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KEENE'S HANDBOOK OF GAUGING.

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A HANDBOOK
OF
PRACTICAL GAUGING,
FOR THE
USE OF BEGINNERS,
WITH INSTRUCTIONS IN THE MODE OF ASCERTAINING
THE STRENGTHS OF SPIRITS BY MEANS OF
SIKES'S HYDROMETER,
AND AN EXPLANATION OF THE THEORY OF ITS
ACTION;

TO WHICH IS ADDED,
A CHAPTER ON DISTILLATION,
DESCRIBING THE PROCESS IN OPERATION AT THE
CUSTOM HOUSE FOR ASCERTAINING THE
STRENGTHS OF WINES.

ILLUSTRATED WITH DIAGRAMS.

BY JAMES B. KEENE,
OF H. M. CUSTOMS.

LONDON: F. PITMAN, 20, PATERNOSTER ROW,
AND ALL BOOKSELLERS.
1861.

183. c. 39.

BIBLIOTHECA · BODLEIANA ·

HANDBOOK OF PRACTICAL GAUGING.

GAUGING is that branch of Practical Geometry which treats of the Mensuration or Measurement of Vessels intended to contain Liquids, in order to ascertain the quantity they are capable of holding when filled, and the quantity they actually contain when partially full. The former is technically called "the Content," the latter "the Ullage."

The mode of calculation depends on the figure of the vessel and the unit of measurement employed.

In ordinary mensuration, the unit of comparison is the yard, its multiples, or sub-multiples, as inch, foot, &c. In Gauging, the imperial gallon is the unit, which, although in no way derived from the yard or any of its divisions, yet bears a certain fixed relation thereto, and can be at pleasure resolved into those dimensions.

It is possible to acquire the practice of Gauging (reduced as it is in many respects to an almost mechanical operation) without any knowledge of the principles on which it is based. Yet, doubtless, an intelligent acquaintance, even though slight, with the mathematical groundwork of the science, must give more certainty to the operation, and greater correctness to the result.

This treatise is intended more as a Manual, or first book, laying down in general terms the principles and practice of Gauging, than as treating deeply and philosophically of the subject; the purpose is more to simplify than to elaborate; and, beginning so as to give the student, who may be totally ignorant of Geometry, some insight into the science, it may perhaps stimulate him to further study.

Gauging is strictly a Geometrical operation, and to understand it thoroughly it should be seen from its first principles. I would therefore recommend all who require a knowledge of it to endeavour thus to see it, convinced that by so doing they will add an interest to a duty too generally considered monotonous and mechanical.

It must, however, be borne in mind that the most extensive theoretical acquaintance with the subject will of itself never make a man a practical Gauger; the vessels in general use, on which he has to exercise his skill, differ so much from what a Geometrician would call the fundamental figure, that variations in treatment are required, with which practice alone can familiarize him. Theory and practice must go hand in hand; for where the one may fail, the other will, without doubt, bring the matter to a successful issue.

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SIGNS AND TERMS USED IN THIS WORK.

$+$ Plus, sign of addition; as, $4 + 6$, or 4 added to 6.

$-$ Minus, sign of subtraction; as $7 - 5$, or 7 less 5.

$\times$ Sign of multiplication; as 7×5, or 7 multiplied by 5.

$\div$ Sign of division; as $18 \div 6$, or 18 divided by 6.

$=$ Sign of equality; as $4 + 7 = 11$, or 4 plus 7 equal to 11.

: Sign of ratio or relation; as 4 : 9 means the ratio of 4 to 9; read 4 is to 9.

: : Sign of equality of ratios; thus 2 : 6 : : 3 : 9 indicates a like relation between 2 and 6 to that between 3 and 9; read 2 is to 6 as 3 is to 9.

O.P., Overproof.

U.P., Underproof.

FAHR. or F., Fahrenheit's Thermometer

BOUGE, the bilge, bulge, or swelling out of a cask.

CHIMB or CHIME, the edge or brim of a cask formed by the ends of the staves.

QUARTER, the part between the bouge and chimb.

HEAD, the flat end of a cask.

FRONT HEAD, the one on which the gauges are marked, with other particulars.

SCOTCHES, wedges used to fix casks in position for gauging.

ULLAGE, strictly, the quantity a cask wants of being full. It is derived from the Latin *uligo*, ooziness, indicating loss by the oozing of the liquor. In practice, however, it is used for the liquor in the cask when partially full; and "Content" for the capacity of a cask, whether full or empty.

GEOMETRICAL DEFINITIONS.

A KNOWLEDGE of the meaning of the terms used in any Science is indispensable to the commencement of its study. The Student is therefore desired to make himself thoroughly acquainted with the following definitions, which have been arranged with a view to the ultimate purpose of the book.

1. A Solid is a body having extension in three directions, namely, length, breadth and depth, or thickness.

In a geometrical sense the term solidity refers principally to bulk or space occupation, and it is in that sense equally applicable to liquids, as to solids specifically so called; the real distinction being, that solids retain their shape by virtue of some inherent force, while liquids suit theirs to the form of their containing vessel, changing their figure without varying their bulk. Figure is, however, an essential character of a solid; and when calculating the bulk of any object a fixed outline is presumed if it do not exist.

In mensuration of solids the cube is generally taken as the standard, as being a body of the simplest kind, having its length, breadth, and thickness equal to each other. Thus, in speaking of the magnitude of a body, we say that it has so many cubic feet, inches, yards, &c., in it; that is to say, that its bulk is sufficient to form so many cubes of either of those dimensions.

2. A Surface has extension only in two directions, namely, length and breadth.

In examining a cube we find it gives us a certain impression called solidity; it occupies space,—that is to say, it has bulk. It also has six faces or boundaries. Now, if we speak of the dimensions of these faces, we have to leave one of the constituents of solidity out of the question; each face has length and breadth, but *no* depth, and consequently no solidity. These faces are called superficies, or surfaces, which are defined as being length and breadth without thickness. This is true of superficies of any and every kind, and the idea of thickness must not be retained. If surface implied thickness, the greater the surface, the greater would be the bulk. But this is evidently not the case;—for instance: a cubic inch of gold has a surface equal to six square or superficial inches, but it may be beaten out so that its surface is almost indefinitely increased, while its actual bulk is the same as before.

3. A Line has extension in length only.

Every surface is bounded by lines. Here, again, another dimension, namely breadth, is put aside, and length alone remains. A line, therefore, has no reference to any other dimension than length; and in speaking of the lines that bound a superficies we mean only the lengths of the boundaries. For, if we divide a surface into any number of smaller surfaces, although the lengths of the boundaries must be evidently increased by every such division, the total of the smaller portions must be still equal to the entire surface.

4. A Point is position only, and has no dimension. The extremities of a line are points.

If a line be length without breadth, a point or position in that line can have neither length nor breadth. Wherever a line is supposed to be divided, there is a point; but if a line be divided into any number of shorter lengths, the total sum of these must make up the entire length, the points having reference merely to the commencements of each division;—thus, in a line divided by a certain point in the centre, each portion is half the whole line; but were the dividing point possessed of length, one or both parts must be diminished to such extent, and they would not be halves of the entire line.

We have thus arrived at the four definitions which may be said to be primary ones, and which in their mathematical sense are pure abstractions, but which, once understood, render the rest easy, as all other definitions of figures are merely specific varieties of them, the principal of which now follow.

5. A Straight Line is the nearest distance between two points.

6. The intersections of lines with one another are points.

7. If two straight lines coincide in any two points, they must coincide altogether; they cannot therefore enclose a space.

8. A Curved Line, or Curve, has no portion of its length straight.

9. When two lines meet or cross each other, the space between them is called an Angle; if the lines be straight it is a

plane angle, and the distance between the lines is the measure of the angle. Plate I., Fig. 1.

10. Angles are of three kinds. Fig. 2.

a. The Right Angle.—If one straight line standing on another straight line makes the adjacent angles equal to one another, each is called a right angle, and the line standing on the other is said to be perpendicular to it.

b. The Obtuse Angle, which is greater than a right angle.

c. The Acute Angle, which is less than a right angle.

11. A plane superficies is one, in which a straight line joining any two points in its surface will touch the superficies throughout its entire length.

NOTE.—When it is said of lines that they are on the same plane an imaginary plane or level surface is supposed on which they would lie; and figures are said to be plane when they form part of such a surface.

12. When two straight lines on the same plane are in such a position with respect to each other that, if continued indefinitely in either direction they would never meet, they are said to be parallel. Fig. 3.

13. A Figure is a portion of space enclosed within one or more boundaries, and is either a surface or a solid; the space included is, in comparison with other figures, called the area or solidity.

14. Figures are named from the character and number of their boundaries, and are regular or irregular.

15. A Circle is a plane figure, enclosed by a single curved line called the circumference, which is everywhere equi-distant from a certain point within, called the centre. A *radius* is a straight line drawn from the centre to any part of the circumference. And a straight line through the centre, terminated at each end by the circumference, is called the diameter, and equals two radii. Fig. 4.

16. An Arc of a circle is any portion of its circumference.

17. A Chord is a straight line joining the ends of an arc.

18. A Segment is the space included between an arc and its chord.

19. An Ellipsis is a plane figure bounded by a single curved line or circumference, which is so disposed with regard to two points within it, that if from any point in the circumference two straight lines be drawn to these points, their sum will be always the same. These points are called the foci. Fig. 5.

> NOTE.—If two pins be fixed in a board, and a piece of string of a greater length than double their distance apart be tied at the ends and thrown round them, and then, by the point of a pencil, stretched lightly, so as to form a triangle, the pencil will, if moved round within the limit of the tension of the string, describe an ellipsis. In this case it will be evident that if the portion of the string between the points be omitted from the calculation as being the same throughout, the remaining portion, which forms the other two sides of the triangles, must, whatever their position, be equal at all times; and these two sides are the two lines described in the definition.

20. A straight line passing through both foci and terminating each way in the circumference, is called the transverse, or longer axis or diameter.

21. The centre of this line is the centre of the ellipsis.

22. A straight line through the centre perpendicular to the transverse axis, is called the conjugate or shorter axis.

23. An Ordinate is a straight line perpendicular to the transverse axis, joining it to the circumference; if it be continued right through the figure, it is a double ordinate.

24. A Parabola is the curve described by bodies projected with any force, they being acted upon at the same time by the force of gravity. Thus, a ball fired from a gun describes a parabola; so also does a jet of water running out of the side of a vessel. The character of the line will be best seen by describing the mode of drawing it by finding points in a curve. Fig. 6.

Let the axis AB and the double ordinate CD be given. Through A draw EF parallel to CD; and through C and D draw CE and DF parallel to AB and cutting EF at E and F. Divide BC and BD into any number of equal parts (the more the better), and divide CE and DF each into the same number. From the divisions in CE DF draw straight lines to the point A; and from the divisions in CB BD draw straight lines parallel to AB, cutting the lines 1A, 2A, &c. The points where these lines cross will be in the curve of the parabola. AB is the diameter; BD or CB ordinates; CD a double ordinate.

25. Rectilineal figures are contained by straight lines.

26. Trilateral figures, or triangles, by three straight lines.

27. An equilateral triangle has all its sides equal. Fig. 7.

28. An isosceles triangle has two equal sides. Fig. 8.

29. A scalene triangle has all its sides unequal. Fig. 9.

30. A right angled triangle has one right angle. Fig. 10.

31: An obtuse angled triangle has one obtuse angle. Fig. 9.

32. An acute-angled triangle has three acute angles. Fig. 7.

33. Of quadrilateral or four-sided figures, parallelograms are plane rectilineal figures, having their opposite sides equal and parallel: of these,

24. A Square has all its sides equal, and its angles right angles. Fig. 11.

35. A Rhombus has all its sides equal, but its angles are not right angles. Fig. 12.

36. A Rectangle, or Oblong, has only its opposite sides equal, and all its angles right angles. Fig. 13.

37. A Rhomboid has only its opposite sides equal, but its angles are not right angles. Fig. 14.

38. A Trapezium is a four-sided figure whose sides and angles are all unequal; when two of the sides are parallel it is called a Trapezoid. Figs. 15 and 16.

> NOTE.—Any side of a rectilineal figure may be called its *base*. In a right angled triangle the side opposite the right angle is called the *hypotenuse*, either of the others the *base* or *perpendicular*. In an isoceles triangle, the side not being one of the equal sides is the *base*. The angle opposite the base is the *vertex* or *vertical angle*. The *altitude* of a parallelogram or triangle is a perpendicular from the opposite side or angle to the base.

39. The straight line joining the opposite angles of a parallelogram is the Diagonal. AB, fig. 11.

40. All figures of more than four sides are called Polygons,

and are regular or irregular, according as their sides and angles are all equal or not:

41. All regular polygons can be inscribed in circles. They are named from the number of their sides, as Pentagons (5 sides), Hexagons (6 sides), &c. Figs. 17 and 18.

> NOTE.—A figure is said to be inscribed in a circle when all its angles touch the circumference, and a circle is said to be inscribed in a figure when the circumference touches all its sides.

42. A Cube is a solid having six equal squares for its sides. Fig. 19.

43. A Parallelopipedon has six rectangular sides, of which the opposite pairs only are equal and parallel. Fig. 20.

44. A Prism is a solid whose ends or bases are equal and parallel plane figures, and its sides are parallelograms. Fig. 21.

> NOTE.—Prisms are named from the figure forming their bases, as "triangular," "square," "pentagonal," &c.

45. A Cylinder is a solid having for its ends two equal and parallel circles. Fig. 22.

> NOTE.—It may be considered as generated by the revolution of a rectangle about one of its sides.

46. A Pyramid is a solid having a plane figure for its base, its sides being triangles whose vertices meet in the vertex of the pyramid. Fig. 23.

> NOTE.—Like prisms, these are named from their bases.

47. A Cone is a round pyramid, having a circle for its base. Pl. II., fig. 1.

> NOTE.—It may be considered as being generated by the revolution of a right angled triangle about one of the sides containing the right angle.

48. A Sphere is a solid, of which the outline is everywhere a circle. Fig. 2.

> NOTE.—It may be considered as generated by the revolution of a semi-circle about its diameter.

49. A Spheroid is a solid generated by the rotation of a semi-ellipsis about one of its axes. If round the shorter one, it is

called an oblate spheroid; if round the longer one, it is a prolate spheroid. Fig. 3.

> NOTE.—An oblate spheroid resembles an orange, or a skittle bowl; a prolate one is like an egg with its ends equal.

50. A Paraboloid, or Parabolic Conoid, is a solid generated by the revolution of a semi-parabola round its axis. Fig. 4.

51. The Axis of a solid is a line passing through its centre and joining the middle of both ends. When the axis is perpendicular to the base the solid is said to be *right* or *upright*, otherwise it is *oblique*.

52. The Height of a solid is a straight line drawn from its vertex perpendicular to its base, and in a right prism, pyramid, &c., is equal to its axis; but in an oblique one it is equal to the perpendicular of a right angled triangle whose hypotenuse is the axis.

53. A Segment of a solid is a part cut off from the top by a plane parallel to the base. Pl. I., fig. 23, *a*.

54. A Frustum is the part remaining after the segment is removed. Pl. I., fig. 23, *b*.

55. A Zone of a sphere is the part intercepted between two parallel planes. Pl. II., fig. 2, *a*.

56. A Spindle is generated by the revolution of a curved line about its chord, and is Circular, Elliptic, or Parabolic, according to the figure of which the curve forms part. Fig. 5.

MENSURATION.

In measurements of length or distance there is but one dimension involved, and however the numbers representing the divisions may be multiplied or divided, there is no change in the dimension signified. Thus, 3 yards may be multiplied by 10 for an increased length, and the result will be 30 yards; or the same number may be multiplied by 3 to give the number of feet that make up the 3 yards, namely 9 feet,—and this again by 12 for the number of inches; but length is still the dimension signified, the difference being only in the unit by which it is expressed. But if we multiply 3 feet representing length, by 3 feet representing breadth, the result will be 9 feet representing neither length nor breadth, but extension of surface in both directions.

Let fig. 6 (plate II.) be a square surface, 3 feet each side. If we take one side of 3 feet with a breadth of 1 foot, it will be evident that there will be the same number of square as of linear feet in such portion; but, as the total breadth of the figure is 3 times this, there must be 3 times this number of square feet, thus giving 9 feet for the entire surface, which is equal to multiplying one side by the other. This, of course, is true of any other divisions; thus, as each square foot has a side of 12 inches, 12×12=144, or the number of square inches in each square foot, and this total multiplied by 9 will give 1,296, or the number of square inches in a square yard.

In the third species of measurement, which appertains to solids or figures having three dimensions, the thickness or depth has to be multiplied into the product of the length and breadth to give the solidity.

Thus, for instance, let us suppose that the surface we have just now been considering is the side of a cube, as in fig. 7. This figure, then, is 3 feet long, 3 feet broad, and 3 feet deep. Taking the surface as before, it consists of 9 square feet. If we suppose a slice or section of the cube cut off at a depth of 1 foot, we shall have as many cubic feet as there are superficial feet, viz. 9; but as there are three such sections, the total number will be 3 times 9, or 27 cubic feet, which will be the solid content of the cube in question, the unit of measurement being feet. If the unit, however, be a yard, then the side of 3 feet=1 linear yard; the surface of 9 square feet=1 square yard; and the solidity of 27 cubic feet=1 cubic yard; a dimension which is, under many circumstances, employed as a unit of measurement.

OF SURFACES.

To find the Areas of Parallelograms.

Rule.—Multiply the base by the perpendicular height, and the product will be the area.

Note.—In a square, this will be the same as multiplying the length of a side by itself. In a rectangle, it will be to multiply the length by the breadth, as in each instance the sides are perpendicular to each other. In the case of a rhombus or rhomboid, the perpendicular height is always less than the side. Thus, in Pl. II., fig. 8, ABCD is a rhomboid, of which FD is the perpendicular height. Now, in multiplying the length CD by the height FD we evidently get the area of a rectangle EFCD; but this rectangle is equal to the rhomboid ABCD, it being formed by cutting off the triangular piece FDB, and adding the same at EAC.

If the side of a square be 4, what is its area? Ans. 16.

If the side of a square be 4769 miles, what will be the area? Ans. 22, 743, 361.

If the side of a square be 24ft. 6in., what is its area? Ans. 600ft. 3 parts.

The sides of a rectangle are 7 and 4, what is its area? Ans. 28.

What is the area of a lawn whose length is 40ft., and breadth 25ft. Ans. 1,000 square feet.

How many square feet of carpet in a room 24ft. 6in. by 18ft. 9in.? Ans. 459ft. 9 parts.

What is the area of a rhombus whose side is 3 yards, and height 3ft. 6in.? Ans. 31ft. 6 parts.

To find the Area of a Triangle.

Rule.—Multiply the base by the perpendicular height, and half the product will be the area.

Note.—By adding a similar and equal triangle to the one to be measured, a parallelogram is obtained, the area of which is found by multiplying the base into the height; but as this parallelogram is twice the size of the triangle, the product must be divided by two for the area of the triangle.

Thus, to the triangle ABC, fig. 9, add the equal triangle ACD; ABCD will be a parallelogram, of which AE is the perpendicular height, as it is also of the triangle.

What is the area of a triangle whose base is 14, and perpendicular height 24? Ans. 168.

If a triangular field is 164 feet at the base, and its perpendicular height is 96 feet; what is its area in square yards?
Ans. 875 one-9th yds.

When the Three Sides of a Triangle are given.

Rule.—From half the sum of the three sides subtract each side separately; then multiply the half sum and the three remainders together, and the square root of the last product will be the area.

What is the area of a triangle whose sides are 50, 40, and 30?
Ans. 600.

To find the Area of a Trapezium.

Rule.—Join two opposite angles by a diagonal, thus dividing the figure into two triangles, the areas of which, found as above and added together, will give the area of the figure. Or,

Rule 2.—Draw perpendiculars from the opposite angles to the diagonal, and multiply the diagonal into half the sum of these perpendiculars for the area.

Note.—The diagonal is the base common to both triangles, and multiplying it into the two perpendiculars will give double the areas of the two triangles. Halving the sum of these perpendiculars has the same effect as halving the double area when found.

The four sides of a trapezium are AD 15, DC 13, CB 14, and AB 12, the diagonal AC 16; what is the area? Ans. 172·5247.

In the trapezium ABCD, fig. 5, the diagonal AC is 24, the perpendiculars DE 6 and FB 12; what is the area? Ans. 216.

To find the Area of a Trapezoid.

Rule.—Multiply half the sum of the parallel sides by the perpendicular distance between them, and the product will be the area.

In the trapezoid ABCD, fig. 11, if we divide the side AC in the centre at E, and through E draw GF parallel to BD, and produce AB to G, a parallelogram GBFD is formed, which is equal to the trapezoid; the triangle GEA which is added, being equal to the triangle ECF which is taken away; and the sides GB and FG are each equal to the half sum of the two sides of the trapezoid AB and CD; but the area of the parallelogram is found by multiplying its length by its perpendicular height, and as it is equal to the trapezoid, the area of the latter must be found by the same means.

What is the area of a trapezoid whose parallel sides are 28 and 36, and perpendicular distance between 14? Ans. 448.

To find the Area of a Regular Polygon.

Rule.—Multiply half the sum of all the sides by the perpendicular drawn from the centre of the figure to one of the sides, and the product will be the area. This perpendicular will be the radius of a circle inscribed in the polygon.

Note.—A polygon may be considered as made up of as many equal triangles as there are sides to the figures, their vertices uniting in the common centre of the figure; so that whether we find the area of one triangle and multiply that by the number of sides, or multiply the number of sides by the height of the triangles, and take half the sum, or, as in the rule, multiply by half of one of the dimensions, the result will be the same.

The side of a pentagon is 20 yards, and the perpendicular from the centre to the middle of the side 13·76382; what is the area? Ans. 688·191 square yards.

OF THE CIRCLE.

The diameter of a circle bears a fixed proportion or ratio to its circumference, the three following formulas being most commonly used to express the ratio:

As 7 : 22 :: diameter : circumference
As 113 : 355 :: diameter : circumference
As 1 : 3·1416 :: diameter : circumference

The diameter of a circle being given, to find the circumference.

Rule.—Make use of either of the ratios in the order above given.

The circumference being given, to find the diameter.

Rule.—Reverse the ratio, and proceed accordingly.

Thus, 22 : 7 : : circumference to diameter, &c.

What is the diameter of a circle whose circumference is 50? Ans. 15·909.

The diameter of the Earth is 7958 miles, what is its circumference? Ans. 25000.8528.

The circumference of a circle is 27, what is the radius? Ans. 4·297.

To find the Area of a Circle.

Rule 1.—Multiply half the circumference by half the diameter for the area.

Note.—A circle is equal to a right angled triangle whose base is equal to the circumference, and height to the radius. Or, a circle may be considered as a polygon having an infinite number of sides; and its area, as found by this rule, is on the principle that each side is the base of a triangle whose vertex is the centre of the circle, the circumference being the sum of all the sides. See rule for polygons.

Rule 2.—Multiply the square of the diameter by ·7854 for the area.

Note.—·7854 is the area of a circle whose diameter is 1. The square of 1=1; therefore, as 1 : ·7854 : : diameter squared : the area; that is, as one square is to its inscribed circle, so is another square to its inscribed circle. Pl. II., fig. 12.

Rule 3.—Multiply the square of the circumference by ·07958.

Note.—·07958 is the area of a circle whose circumference is 1.

Rule 4.—As 14 : 11 so is the square of the diameter to the area.

Rule 5.—As 88 : 7 so is the square of the circumference to the area.

Example.—Find the area of a circle (by each of the above rules) whose diameter is 1, and circumference 3·1416.

Rule 1.

1·5708=½ cir.
·5=½ dia.
·78540 area

Rule 2.

1 sq. dia.
·7854
·7854 area

Rule 3.

9·86965 sq. cir.
·07958
6908755
8882685
4934825
7895720
·7854267470 area

Rule 4.

1 sq. dia.
11
14 | 11
·7857 area

Rule 5.

9·86965 sq. cir.
7
88 | 69·08755
·785085 area

What is the area of a circle whose diameter is 15 yards?
Ans. 176·715 square yards.

What is the area of a semicircle, of which 20 is the radius?
Ans. 628·32.

The circumference of a circle is 91, what is the area?
Ans. 659·00198.

To find the Area of an Ellipsis.

Rule.—Multiply the transverse by the conjugate, and the product by ·7854, for the area.

Note.—The ellipsis bears the same relation to the rectangle within which it is inscribed, as the circle does to the square whose side is equal to its diameter.

The transverse diameter is 70, and the conjugate 50, what is the area of the ellipsis? Ans. 2748·9.

The diameters of an ellipsis are 5 and 2, what is the area?
Ans. 7·854.

OF SOLIDS.

To find the Solidity of a Cube.

Rule.—Multiply the length of a side by itself, and this product by the side again, the last product will be the solidity. See fig. 7, plate II.

The side of a cube is 12, what is the solidity? Ans. 1728.

What is the solidity of a cube 6ft. 6in. each side?
Ans. 274ft., 7 parts, 6 thirds.

What is the solidity of a cube whose side is ·86? Ans. ·636056.

To find the Solidity of a Parallelopipedon.

Rule.—Multiply the length, breadth, and depth together.

What is the solidity of a parallelopipedon whose length, breadth, and depth are 10, 4, and 5? Ans. 200.

To find the Solidity of a Prism or Cylinder.

Rule.—Multiply the area of the base by the perpendicular height, and the product will be the solidity.

Note.—This rule applies equally to right or oblique prisms or cylinders. For, a cylinder may be considered as made up of an infinite number of circular plates piled on each other; and the perpendicular height must be the same whether piled obliquely or not.

How many cubic feet of water will a hollow square prism contain, each side of the base being 2 feet, and the height 10 feet? Ans. 40 cubic feet.

What is the capacity of a cylinder 44 inches in circumference, and 33·64 inches high? Ans. 5184 cubic inches.

What is the solid content of an oblique cylinder, the diameter of whose base is 10 feet, and height 10 feet? Ans. 785·4.

To find the Solidity of a Cone or Pyramid.

Rule.—Multiply the area of the base by one third the perpendicular height, and the product will be the solidity.

Note.—A cone or pyramid is equal to one third the solidity of a corresponding cylinder or prism of the same base and height; hence the rule.

The diameter of the base of a cone is 12 feet, and its perpendicular height 100 feet, what is its solidity? Ans. 3769·92.

Each side of the base of a triangular pyramid is 3, and height 30; what is the solidity? Ans. 38·97117.

To find the Solidity of a Frustum of a Cone or Pyramid.

Rule.—Add the areas of the two ends and the mean proportional between them together, and the sum, multiplied by one third the perpendicular height, will be the solidity.

Note.—The mean proportional is found by multiplying the areas of the two ends together, and taking the square root of the product.

What is the content of the frustum of a square pyramid, the areas of the ends being 504 and 372 square inches, and the perpendicular height 31½ feet? Ans. 95·447 cubic feet.

What is the solidity of a conic frustum, whose height is 20 inches, and the diameters of the ends 28 and 20 inches?

Ans. 5·284.

To find the Solidity of a Sphere.

Rule 1.—Multiply the cube of the diameter by ·5236 for the content.

Rule 2.—Multiply the diameter by the circumference, and the product by one-sixth of the diameter, for the solidity.

Note.—The reason of the first rule is because a sphere is equal to two-thirds of a cylinder of the same diameter and height; and as in a cylinder we should multiply the square of the diameter by ·7854, and this again by the height, for the solidity, which in a cylinder whose diameter and height are equal, would be the same as cubing the diameter and multiplying by ·7854,—so, in the case of a sphere, we cube the diameter and multiply by ·5236, which is two-thirds of ·7854.

The second rule is because a sphere may be considered as composed of an infinite number of little pyramids, whose bases form its surface, and whose vertices meet in its centre; and to multiply the diameter by the circumference, is to find the surface of the sphere, which is, of course, the sum of their bases; and to multiply this by one-sixth the diameter, is the same as by one-third of their height (see rule for pyramids), and will therefore give the sum of their entire solidity.

What is the solidity of a sphere whose diameter is 3?

Ans. 14·1372.

What is the solidity of a sphere whose diameter is 24 inches?

Ans. 7238·2464 cubic inches.

What is the solidity of the Earth, if its circumference be 25,000 miles? Ans. 263858149120 cubic miles.

To find the Solidity of a Spheroid.

Rule.—Multiply the square of the revolving axis by the fixed axis, and the product by ·5236, for the solidity.

Note.—In a prolate spheroid the longer is the fixed, and the shorter the revolving axis; in an oblate spheroid the contrary is the case.

What is the solidity of a prolate spheroid whose longer axis is 55, and shorter 33? Ans. 31361·022.

What is the solidity of a prolate spheroid whose axes are 10 and 5? Ans. 130·9.

What is the solidity of an oblate spheroid whose axes are 20 and 10? Ans. 2094·4.

To find the Solidity of a Parabolic Conoid or Paraboloid.

Rule.—Multiply the square of the diameter of its base by ·3927, and that product by the height; the last product will be the solidity.

Note.—A paraboloid is half its circumscribed cylinder; its area may therefore be found by treating it as a cylinder and dividing by 2; or, as in the rule, multiplying by $\frac{\cdot 7854}{2}$=3927.

What is the solidity of a paraboloid whose height is 10, and diameter of base 10? Ans. 392·7.

What is the solidity of a paraboloid whose height is 40, and diameter of base 12? Ans. 2261·952.

The diameter at base of a paraboloid is 24, and height 10; what is the solidity? Ans. 2261·952.

To find the Solidity of the Frustum of a Paraboloid.

Rule.—Multiply the sum of the squares of the diameters of the two ends by the height, and that product by ·3927, for the solidity.

In a parabolic frustum whose height is 12, the diameters of the ends are 20 and 10, what is the solidity? Ans. 2357·4.

The diameters of the frustum of a paraboloid are 15 and 12, and the height 8; what is the solidity? Ans. 1159·8408.

The diameters of the frustum of a paraboloid are 10 and 5, the length 12; required the solidity. Ans. 589·05.

ON THE RATIOS OF SIMILAR FIGURES TO EACH OTHER.

Figures, whether superficial or solid, are said to be similar when, though differing in size, their relative proportions remain the same. Equilateral triangles, for instance, however they may vary in size, must have always their three sides and three angles equal; they are, therefore, always similar ;—so also squares, the regular polygons, and circles, which always maintain their proportions unchanged. In solids—spheres, cubes, and the other four regular solids, are also invariable in their proportions, and consequently always similar. With other figures, they are only similar when all their parts as to lines or superficies are proportionally increased or diminished, and the angles remain unaltered. A rectangle, for instance, whose sides were 2 and 4, would be similar to a rectangle whose sides were 4 and 8, but not to a rhomboid whose sides were 4 and 8, because the latter would differ in the angles.

Similar surfaces bear to each other the same proportions as the squares of their like dimensions. In a square this fact is very palpable: thus, a square whose side is 2, has a surface of 4, which is the square of its side; a square whose side is 3, has a surface of 9, or the square of its side;—therefore, those squares whose sides are 2 and 3, are to each other as 4 to 9, or as the squares. The same would be true if the entire perimeter or boundary of each were taken; that of the first would be 8, of the second 12, the squares of which are 64 and 144, and which are to each other as 4 to 9;—so, also, if the diagonals of each were taken as the dimension. Circles are as the squares of their diameters and circumferences, and the regular polygons as the squares of either of their sides, or of the radii of the circles in which they are inscribed.

With solids, the proportion is as the cubes of their like dimensions. Thus, a cube whose side is 2 has a solidity of 8, and a cube whose side is 3 has a solidity of 27. Their proportions are, therefore, as 8 to 27. So also of spheres or other similar solids, as may be proved by comparing the proportions of their actual solidity with the proportion found in cubing any simple dimension of either.

If a solid be doubled or otherwise increased in one dimension only—say its length, its total bulk is only increased to that amount; if it be increased superficially in the same ratio, that is in the dimensions of length and breadth, the total increase will be as the squares of the dimensions, and if the same amount of increase be made in the depth also, the proportion will be as the cubes. This will appear quite evident by a reference to plate II., fig. 13, in which *a* and *b* are to each other as their lengths; *a* and *c* as the squares of their lengths; and *a* and *d* as the cubes of their lengths;—and this proportion holds good with any rate of increase, however great or minute.

GAUGING.

OF THE IMPERIAL GALLON, AND THE MODE OF MENSURATION ADAPTED TO IT FOR FIGURES OF VARIOUS KINDS.

In the calculations hitherto made, our unit of measurement has been founded on the Imperial Yard and its derivatives. In gauging liquids, however, a different unit is employed—not founded on the yard, but on an original standard peculiar to itself; it is called the Imperial Gallon.

The standard for the Imperial Gallon is the space occupied by 10 lbs. avoirdupoise (or 70,000 grains) of distilled water, taken at the temperature of 62° Fahr., with the barometer at 30 inches. The space thus filled, expressed in cubic inches, is 277·274, a cubic foot of liquid being a trifle over 6 gallons, or nearly 6¼ gallons (6·23). This number, 277·274, is called the Square Divisor for Imperial Gallons, because it is used for the purpose of dividing the number of cubic inches in any vessel, to obtain its contents in Imperial Gallons, as every time the quantity it represents is found in the vessel, so often is there an Imperial Gallon.*

If we suppose a square vessel to be formed, with an area of 277·274 square inches, and of the depth of 1 inch, it is obvious that such vessel would contain the same number of cubic as of superficial inches, or just one gallon; and the side of the square thus formed would be the square root of its area, or 16·65 inches; this is called the Square Gauge Point, or unit of calculation, in gauging square vessels.

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* Before the Imperial Gallon was fixed by law, different measures were used for ale and wine. Ale gallons were 282 cubic inches, and wine gallons 231. To reduce old wine gallons to new, divide by 1·2, or set 5 on the slide at the back of the head rod to 6 on the top of the rule, and under the number of wine gallons will be the Imperial Gallons on the top line of the slide. Multiply old ale gallons by 60, and divide by 59, for Imperial Gallons.

In a square prism, the side of whose base is 16·65 inches, every inch of its depth will represent one gallon, and the total inches in that dimension will stand for the number of gallons it contains. If, however, the sides of the base of the prism were longer than this, say 33·3 inches, or double the former, the area of the base would be increased four times. Each inch of depth would then represent 4 gallons, and the total content be increased in the same proportion. It is therefore evident that, in all square vessels, their area in gallons will be as the square of 16·65 is to the squares of the sides of such vessels; or, taking 16·65 as unity, the square of the side of any vessel taken as a multiple of such unit, will be its area in gallons.

Most vessels for holding liquids have a circular form, and the square divisor and gauge point would be of little or no use in gauging such figures, except by the tedious process of reducing their contents to cubic inches, and dividing by 277·274. In order to avoid this, a circular divisor and a circular gauge point have been obtained, on the same principle as the foregoing. A circle, whose area would be 277·274 inches, and which would, therefore, at the depth of 1 inch, contain a gallon, would have a diameter of 18·789 inches,—or, as usually taken, 18·79; this, therefore, is the circular gauge point, while the circular divisor is the square of such diameter, or the area of a square described about such a circle, which is 353·036, generally taken 353·04. Now, in gauging a cylindrical vessel, if we were to use the square divisor, it would be necessary to square the diameter in inches, and multiply by the length in inches, and then multiply by ·7854 to correct the excess over the true content, before dividing by 277·274. But the use of the circular divisor obviates this, as its excess over the true number of inches in a gallon is in the proportion of 1 to ·7854, and the result obtained in each case is the same. (The square divisor, divided by ·7854, gives 353·036.)*

In gauging a cylindrical vessel, if we calculate from 18·79 as unity (or 1 gallon), and take the diameter of the vessel to be gauged, in multiples or parts thereof, the square of such diameter will be the number of superficial gallons it contains; thus, a cylinder whose diameter is 2·5 (18·79 being 1), will have a superficial area of 6·25 gallons; and this area, multiplied into its length in inches, will give its content in gallons;—if, therefore, its length be 40 inches, its content will be 250 gallons.

If the section of the vessel, instead of being circular, be elliptical, the long and short diameters must be multiplied together, and the product divided by 353·04, for the area in gallons, which, multiplied by the length, will give the content.

Were all casks of the figures we have been describing, or of any plane figure in section, and of uniform diameter, the question of gauging would be very simple. But such is not the case; and, in fact, such figures are only met with in rare and exceptional instances. The most common form for casks is a figure having a circular section with a varying diameter throughout, being widest at the centre, and diminishing gradually towards each end. There are several varieties of form, dependent on the character of the line or curve from the centre to the ends, according to which, different casks, though equal in length, and having the same diameters at the ends and in the centre as each other, would have different capacities. These varieties are theoretically classed into four, which are arranged under certain mathematical figures; and if coopers were mathematicians, and took pains to make their lines according to the exact model laid down, these divisions of figure might be to a certain extent serviceable in practice. As it is, however, they are but of trifling value, and, with the exception of the first, which may be called the model or true form of a cask, they may, without loss, be omitted altogether. We will, therefore, be content with describing them, but in our rules adhere as far as possible to the *practical*, taking theory only as it appertains thereto. The following are the four varieties alluded to :—

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* It may be well here to note that if unity be divided by either of the divisors for squares or circles above mentioned, the quotient is a decimal, which, used as a multiplier in any case in which the respective divisor would be required, will produce the same result. The multiplier for squares thus found is ·0036065; that for circles, ·002832. For instance, let the cubic content of a cask be 46,786 cubic inches:—

46,786÷277·274=168·7 galls.; or, 46,786×·0036065=168·7 galls.

1st. A middle frustum of a spheroid. Defs. 49, 53, and 54.

2nd. A middle frustum of a parabolic spindle. Defs. 24 and 56.

3rd. Two equal frustums of a paraboloid (or parabolic conoid), joined at their bases. Def. 50.

4th. Two equal frustums of a cone, joined at their bases. Def. 47.

It must be evident that, whatever be the figure or capacity of a cask, a cylinder can be supposed of the same length capable of holding the same quantity of liquid, the contents of which may be estimated by the rule laid down above. The diameter of such cylinder would be less than the largest diameter of the cask, and greater than the smallest, and would, in fact, be the mean between them. Pl. III., fig. 1. The first process, then, in gauging, after the dimensions are taken, is to discover this mean diameter, or the diameter of the equal cylinder, which may be done by multiplying the difference between the diameters by a decimal, according to the figure of the cask.

If the difference between the diameters is less than 6 inches, multiply it—for the 1st var., by ·68 ; for the 2nd, ·62 ; for the 3rd, ·55 ; for the 4th, ·5. If the difference be more than 6 inches—for the 1st var., by ·7 ; for the 2nd, ·64 ; for the 3rd, ·57 ; for the 4th, ·52. Add the product thus found to the least diameter, and the sum will be the mean diameter, from which the content can be calculated as for the cylinder.

There are four other rules applicable to the above four varieties, of which it will be sufficient for our purpose to give the one for the first variety, the others being of no practical utility.

Rule.—To the square of the head, or smallest diameter, add twice the square of the bung, or largest diameter, and multiply the sum by the length; then multiply the last product by $\cdot 0009\frac{4}{9}$, or divide it by 1059·1, and either result will be the content in imperial gallons.

Thus, length 40, head 24, bung 32.

$$
\begin{array}{rr}
24\times 24 = 576 & 576 \\
32\times 32 = 1024\times 2 = & 2048 \\
\hline
 & 2624 \\
2624\times 40 = 104960 & \\
\cdot 0009\frac{4}{9} & \\
\hline
944640 & \\
34987 & \\
11662 & \\
\hline
\text{Imp. gall. } 99\cdot 1289 &
\end{array}
$$

The practical objection to these rules is the difficulty of applying them to the casks ordinarily met with, which are never made with sufficient exactness to the mathematical figures to which they refer. In using them, therefore, it will be best to leave out of the question the variety to which a cask belongs, considering it only with reference to a spheroidal figure, and making allowances equivalent to its deficiency therefrom, that its dimensions, calculated according to the rules for such figure, may give the true content. The making such allowances correctly, constitutes the chief art of the practical gauger; and though much aid is given by a theoretical knowledge of the proportions of figures and the principles of geometry, still such knowledge requires to be matured by practice, experiment, and training of the eye and hand; but to this subject we shall have to recur further on, when we have treated on the practice of gauging by the Gauging Rods.

OF THE GAUGING RODS.

These are of four kinds, viz.:—

1. The Bung Rod. Pl. V., fig. 2.

2. The Head Rod. Pl. V., fig. 1.
3. The Long Callipers. Pl. V., fig. 3.
4. The Short Callipers. Pl. V., fig. 4.

Of these, the Bung Rod is the most generally useful. Cylinders can be gauged by it entirely; and small casks of good figure, such as quarter casks or octaves, in most instances exactly, and in all cases with only trifling error; while in larger casks a very useful approximation to the true content may often be made. It is a square rod, about half an inch thick throughout, and 48 inches long, divided on two of its opposite sides into inches and tenths. The other two sides, divided geometrically, are called the diagonal line and the line of imperial areas. The point of the rod is bevelled off, forming a chisel edge, that it may more readily reach into the angle of the chimb of the cask opposite the bunghole, when it is used to compute contents from the *diagonal line*, to be explained presently. There is a brass shoe at the bevelled end, to strengthen it in use, and a sliding brass fitted with springs, which hold it sufficiently to prevent its slipping of its own weight, and yet allow of its being moved freely from end to end. This brass is spread out at its lower end to prevent its passing through the bunghole of the cask, and the springs which sustain it in position are prolonged at the lower part, to the extent of an inch, with notches cut deeply at the half inch and three quarters; and, being placed on each side of the inch lines on the rod, the gauger is enabled to take the internal diameter of the cask at the bung by throwing off at once the thickness of the stave from the length shown.

The line of imperial areas represents the diameters of superficial circular gallons and their decimal subdivisions from 1 to 6 gallons. The division for one gallon coincides with 18·79 inches (or 18 8-10ths nearly), and that for six gallons with 46·02, or just over 46 inches. Now, remembering the relations of similar figures, we know that circles are to each other as the squares of their diameters; the square of the diameter of 6 circular gallons should therefore be 6 times the square of 1 circular gallon; and this is found to be the case. For instance, 18·79 squared is 353·04, and 46·02 squared is 2118·36, which, divided by 353·04, will give 6 as the quotient. This is true of every intermediate division; and the diameter of a circle to contain any number of gallons at 1 inch deep may be found by multiplying the circular divisor 353·04 by the required number of gallons, and taking the square root.

The 4th side, or diagonal, is calculated on the proportion which the diagonal line, or length from the centre of the upper side of a cask to the angle formed by the opposite stave with the head, bears in casks of different sizes. This proportion is, however, fixed only with casks of *similar* figures, or in which the relative proportions of every other dimension remain the same; in which case, the contents of the casks would be as the cubes of the diagonal line;—thus, if the diagonal for 10 gallons be called 1, a diagonal line of twice that length will belong to a cask containing 8 times the quantity, or 80 gallons. Now, on the rule, the division for 10 gallons is opposite 16·44 inches; and the division for 80 gallons is opposite 32·88 inches, or double the length of the other. It is evident that there is no more reason for the diagonal being an unvarying line than any other dimensions; as, if casks were invariably similar figures, the length, or the bung, or the head diameters, as well as the diagonal, might be taken as a basis of calculation. The diagonal, however, has some practical advantages over the rest, that make it the dimension generally used for the purpose.

In Pl. III., figures 2, 3, and 4, although each has the same diagonal, AB, it will be seen that there must be a difference in their capacities, and that consequently the line, if calculated for either figure, would be incorrect for each of the others; it being true of any cask only so long as the triangle ABC retains the same proportions. Notwithstanding this, the diagonal line of the rule can be used in many instances as a sufficient approximation, if occasionally checked by gauging the cask all round. By this means it will be observed if the diagonal line shows more or less than the cask gauges; and by allowing for such difference, a large number of small casks of similar figure and dimensions may be gauged with great facility. The line ranges from 1 to 244 gallons, but is of little or no practical value for casks over 32 gallons; in other words, its use is principally limited to quarter casks and other smaller sizes.

The Head Rod is the next to be described. Its use, as its name indicates, is to take the diameters of the heads of casks; but it is also provided with lines of figures, by which, from the dimensions found, the contents and ullages of the casks may be calculated. It consists of two flat pieces of wood, kept at a certain distance apart by brasses at each end, to allow of a similar piece of equal length sliding freely between them. The length of the rule is 45 inches. The brass at one end is carried up perpendicularly for about 2¼ inches, and then bent laterally to the length of one inch, being somewhat of the shape of the letter Z. This form is adopted in order that the point of the brass may be placed in the angle of the chimb, and yet the rule be kept in such a position as to allow the sliding piece to pass over the ends of the staves without touching them. The lower half of the rod is divided into a scale of inches and tenths, commencing from the end of the bent brass, and reading from right to left. At 12 inches from the left end of the slide there is a short upright brass called the cock, from which, reading from left to right, the line of inches is continued from the lower half of the rule as far as 76, for the purpose of taking the diameter of the heads of casks which exceed 45 inches. The lower part of the slide, on the left of the cock, is divided into two lines, the lowest being a line of inches and tenths from 1 to 12, and the one above being a line of divisions, called the spheroidal line. Above this again, and extending the whole length of the slide, is another geometrical line of mean cylindrical bung diameters, being the diameters of circular areas from the gauge point 18·79 to 70, or from 1 gallon to 13·87. On the upper part of the rule is a line of divisions from 25 to 440, representing the lengths of casks, and also their contents.

A more conveniently divided Head Rod, by which smaller casks may be cast out without the dimensions being doubled, is sometimes used. In it the line of diameters on the upper part of the slide is continued beyond the gauge point to the left as low as 14 inches; and the line on the upper part of the rule runs from 17 to 300.

The back of the head rod has four lines of divisions; the lower part of the rule being a line of segments from 1 to 100. The upper line on the rule, and the two lines on the slide, are each double radius lines. The face of the rod is employed in casting out the contents of casks, and the back in finding the ullages from the wet inches. The mode of using it will be explained when the mode of obtaining the dimensions has been shown.

The Cross Callipers consist of two rules sliding on each other side by side, each having at one end a light piece fixed firmly at right angles downwards; the whole instrument forming three sides of a parallelogram, of which the upper horizontal one is capable of being extended or contracted, increasing or diminishing the distance between the two other parallel sides or arms, at the same time keeping them parallel, whatever their distance apart, this distance being shown by a line of inches, from 1 to 59, on the upper sides of the sliding pieces. The inches read from left to right on the near piece of the slide, and the reverse way on the other,—the first ending, the other beginning, at 29; so that when the ends are placed evenly together, the arms are 29 inches apart. Dimensions greater or less than this are cut by the right end of either slide against the inch line on the other. The instrument will show the diameter of any round vessel, the radius of which is less than the length of its arms. It is used to take the horizontal bung diameters of casks, or "the Cross" as it is called.

The Long Callipers are similarly made, except that the upper sliding portion is longer, and the arms are shorter,—while the latter, instead of being straight, are turned inwards at their ends at right angles for nearly five inches, so as to reach the heads of the casks without touching the projecting ends of the staves; the instrument being intended to take the lengths. The ends are two inches further apart than is shown by the inch line on the upper part of the rule, this being to allow for a supposed thickness of one inch of each of the heads, in which case the internally length of the cask is taken. The instrument general indicates from 1 to 69 inches.

TO GAUGE A SPHEROIDAL CASK BY THE RODS.

Let us now endeavour to apply some of the previous principles to the gauging of a cask, and in so doing explain the mode of using the rules or rods just described. In order to avoid, as far as possible, complicating the question, we will omit any consideration of irregularities of thickness and figure; and, assuming the cask we are about to gauge to be of the exact spheroidal variety, and of the uniform thickness of one inch throughout, we will merely take the dimensions as they are found by the rods, and calculate accordingly for the content.

And here it may be as well to note that, as allowances of one kind or another are almost always necessary, and as to make them properly requires much experience, it is better for the pupil gauger to practice first taking the dimensions of a cask without any reference to allowances, as he can thus familiarize himself with the manner of handling the rules; after which, the varieties of figure and thickness, and the necessary scales of allowances, are more easily appreciated and retained.

To proceed with our cask. In order to gauge it most conveniently, it must be laid horizontally with the bunghole uppermost, and each end equally distant from the ground; and it must be fixed in this position by wedges placed underneath.

The first instrument to use is the cross callipers. Hold it with the left hand nearly in the centre, that it may balance easily, by the portion of the slide towards you, and with the right hand take hold of the arm on the right side a little way down. The instrument being very light and springy must be managed gently, and should open and shut with the greatest ease; for if there be any resistance to its free motion, it is apt to be pressed with too much force, and from its elasticity the arms *give* on touching the sides of the cask, and the indication on the slide is less than the truth. Holding the rod as above described, and standing opposite the front head of the cask, open it wide enough to clear the bung diameter, and, letting the upper portion cross the bunghole, and the arms hang straight down on each side, bring the left arm of the rod to touch lightly against the side of the cask, and close the rule until the right arm touches the other side. The dimension will then be shown on the line of inches at the top of the slide. In the present instance, let the diameter shown be 33·2. This is the outside measurement; but as it is the internal diameter that is required, you must take off two inches for the thickness of the staves, which in our supposed cask is equal to 1 inch on each side. This will give 31·2 as the internal diameter at that part, which you will mark on the bouge of the cask to the right of the bung. Now, take the bung rod in the right hand, and pass it through the bunghole until the point touches the bottom of the cask at the part immediately under, and slide the brass until the flat part rests on the bungstave; then, taking care not to shift the position of the brass, withdraw the bung rod far enough to enable you to read at what point on the line of inches the brass stands. This must be read from the extreme end of the brass springs to allow one inch for the thickness of the bungstave. Suppose in the present instance the diameter thus indicated be 31·4; on comparing this (the perpendicular bung) with the cross or horizontal bung previously taken, you will find it is two-tenths more; take then the mean between them, 31·3, for the true bung, and mark it with chalk on the head of the cask.

The next process is to take the length by means of the long callipers. This instrument is held on a similar principle to the cross callipers as regards the hands, only that the arm of the rod which is to touch the back head of the cask is to be thrown out from you, so as to pass the ends of the staves, and then brought lightly against the back head, while the near arm must be brought gently to touch the opposite portion of the front head, and the length read on the line of inches. The length is taken generally in three positions, that is, from centre to centre, and on each side of this centre, the mean between the three being the proper length; thus, if we found the three dimensions 49·6, 49·8, and 49·7,—by adding the tenths together, and dividing by 3, we obtain 49·7, which is the mean of the three. The actual distance between the ends of the instrument is, as we before described, two inches more than is indicated; we have therefore in this instance the true internal measurement without deducting, as was requisite in the case of the cross diameter.

The next dimension to be obtained is the head diameter, which is taken by the head rod, and is a mean between the diameter of the back and front heads.

The heads of casks are formed of flat pieces of wood placed side by side, and cut into a circular shape. Being subjected to an extraordinary pressure from the hoops which hold the cask together, there is frequently a slight amount of compression across the grain of the wood, so as to give the head a somewhat oval shape; and although coopers in cutting out the heads make some slight allowance for this, it is not always sufficient. The grain of the wood is generally so arranged as to stand perpendicularly when the cask is placed for gauging, bung upwards. It follows that the perpendicular diameter would be liable to be too great, and the horizontal too little; so that to get the medium it would be best taken at an angle of about 45°, or half way between the two. This, therefore, is the way in which it is usually taken, and it is also the most convenient position for rapid gauging.

Hold the head rod then with its face towards the cask, and the crooked brass at the end depressed, so that the rod shall be across the head of the cask in the position just mentioned, namely, at an angle of 45°, and insert the point of the brass into the angle or chimb of the cask. It must be grasped lightly in the left hand near the other end, the principal hold being on that side of the rule which is uppermost, between the finger and thumb, the other fingers of the hand passing round the rest of the rule with just sufficient pressure to keep it in place, as from its thinness it is apt to deflect from the straight line. The slide will then be free to move easily backwards or forwards, and, holding the brass cock between the finger and thumb of the right hand, bring it to the ends of the staves near your left hand. It is a matter that varies in different casks as to what point in the staves to take; the rule is, to take as nearly as possible that part which from its position must be opposite the angle of the chimb *inside* the cask (in the one we are gauging this will be nearly the outside of the stave). When the rule is thus adjusted to the proper position, grasp it more firmly in the left hand to fix the slide; remove it from the cask, and read the diameter on the line of inches on the lower part of the face of the rule, at the point opposite the brass cock. The back head must be first taken this way, and the dimension marked on the right of the bunghole as you stand when taking it. Then, coming again round, take the front head, and compare with the back head, as marked on the bouge. Suppose the back head in the present case 22·8, and the front head 22·6, the mean will be 22·7, which mark on the head of the cask between the *length* and *bung*. Our dimensions will now stand thus: length 49·7, head 22·7, bung 31·3; and the head rod, having just been used to take the head diameter, will be convenient for the next operation, which is casting out the content. To do this, adjust the cock to the mean head diameter thus found, and look along the lower line of the rule for the bung diameter;—exactly over this on the middle or spheroidal line of the slide will be found 6; look for this on the line of inches on the slide below it, and immediately under, on the inch line of the rule, will be found the mean cylindrical bung—28·7 inches, which is, as was explained before, the diameter of a cylinder that, at the same length as the cask, would contain the same quantity of liquor. Now set the gauge point which is on the upper line of the slide to the length 49·7 on the upper line of the rule, and look along the upper line of the slide for the mean cylindrical bung, above which, on the rule, will be found the content of the cask, which in the present instance will be 116 gallons. You have now obtained the content of the cask;

but if it have liquor in, and be not quite full, it will require another process to find the ullage. Set the brass on the bung rod to the mean bung as first found, namely 31·3, and having wiped the rule dry on the inch line for a short distance near the top, re-insert it in the cask until the brass touches the bungstave, taking care that it does not slip; then, quickly withdrawing it, note where the liquor has marked the rule, and write down this height on the head of the cask *under* the bung diameter. Now turn to the back of the head rod, and bring the bung diameter 31·3 on the lower line of the slide over 100 on the segment line, noting what division on the segment line is under the ullage on the lower line of the slide. This found, place the slide so that the corresponding division on it shall be over 100 on the segment line, and then look for the content of the cask on the upper line of the rule, under which, on the slide, will be the ullage required.

When the dimensions of casks are smaller than the head rod is calculated for, they must be doubled, and the content thus found reduced afterwards. If the mean bung be doubled, it will be equivalent to doubling the figure in two dimensions (breadth and depth), and therefore the content will be four times more than required; if the length be doubled—as but one dimension is involved, the content is only doubled,—while if both length and mean bung are doubled, the result is 8 times more. So, when the dimensions are too large; if the mean bung be halved, the content found will be one fourth part of the truth; if the length be halved, the content will be halved also; and if both dimensions be halved, the content will be one eighth of the actual content. [See chapter on ratios of figures, page 17.]

Were casks all of similar figure, and of known and uniform thickness throughout, there would be little or no difficulty in arriving at their true contents, and the above formula would answer for all sizes. As it is, however, not only are casks *never* true mathematical figures, being at best only approximations, but even as such they vary excessively, great differences often existing between casks of the same manufacture and dimensions, although the original intention may have been to make them exactly alike.

In the first place, the wood used by coopers is not sawn, but rent or hewn into shape, in order that the fibre may retain its utmost strength. The thickness is, therefore, never uniform. Again: the outlines of the staves, and hence the figure of the cask, are produced under the guidance of the eye alone; and although coopers by long practice become extraordinarily expert, it is evident that the line of curvature so formed cannot possibly be mathematically correct, or even in its own form invariable. It therefore not unfrequently happens that a cask may have a fine, full figure on one side, and a spare and bad one on the other,—so that it would be likely to be either under or over gauged, according to the portion that may be uppermost; this inequality of figure being rarely perceptible, unless the cask be placed upright on its head and viewed from all sides. Again: a cask whose outward figure shall betoken every good point may, from inequality of thickness within, be nearly the reverse, as, in making up the casks, the staves are often thinned at the bouge to facilitate their curvature, and at the chimb to equalize them and improve the outward appearance, while the internal thickness and inequalities are left untouched elsewhere; on the contrary, some casks are purposely thinned at the quarter, and at the bung and chimb are left of their full thickness. It is evident, therefore, that the thickness of a cask is rarely to be learnt from an examination of it either at the bunghole or at the chimb, and occasional recourse must be had to experimental proof, by boring a hole in certain parts of the cask, and testing the thickness by a graduated wire. But even this is not always to be depended on; for as the adjacent staves vary in thickness, sometimes from one-tenth to half an inch, it is evident that neither would be the true criterion for the whole. A further check is therefore occasionally necessary, and that is the actual proof by measurement in the copper cans, and sometimes the removal of the head of a cask and an examination of its general internal appearance; and a gauger should never lose any opportunity that presents itself of seeing the interior of a cask, or its actual measurement, and comparing results with his general mode of practice. It must not, however, be presumed that these various difficulties are insuperable; nor must the careless gauger excuse himself by the uncertainties that exist. The observant practical man can bring his practice very closely to the actuality. But though at times the best gauger may fail, the cause will most probably be from some unforeseen difficulty, rather than from the habit of taking everything for granted.

There is a certain family likeness continually existing between casks from the same countries and provinces. The art of coopering is an ancient craft, and certain empirical rules and directions are faithfully transmitted from father to son, from master to man,—each country having its peculiar mode of proceeding to work, and its time-worn, time-honoured, ideal or model of perfection. This, therefore, to some extent simplifies the matter, as, from the similarity of make, the casks of any one particular country may be gauged by a similar mode of treatment within a certain range; liable, of course, to such variations as the necessity of any particular instance may require. We shall therefore give, further on, a brief summary of some of the principal varieties of imported casks and their peculiar modes of treatment. It is not at all necessary, in practical gauging, to treat of casks as to their relation to the four varieties previously described, not only from the impossibility of their being made exactly to the model, but from the fact that in practice the third variety, or that which may be considered nearest to it, is rarely, and the fourth *never* met with.

The relative proportions between the four varieties, supposing their dimensions taken for gauging to be the same, are respectively as 116, 111·9, 107·2, 103·3. Now the intervals between these varieties are very wide, being an average of nearly 4¼ gallons in each instance, while no rule is laid down for their calculation. Some other means, therefore, must be devised to meet the case. The best rule in practice is to consider every cask with reference to the spheroidal figure, and after making such allowances as its thickness may render necessary, to consider how far its want of figure detracts from its capacity; an additional allowance to this amount must then be made, and the dimensions thus found, if correctly taken, will be those of a spheroidal cask of the same content, and can then be cast out by the head rod, which is only calculated for the first variety. It is in this that the intelligence and observation of a gauger are apparent; and to do this correctly must be the sole aim of his study.

The allowances for figure may be made on any one dimension, or upon all; and a reference to the figure, Plate IV., will shew the apparent effect of allowance on the length, the result being an imaginary figure between the one under operation and the spheroidal model. In practice it is generally most convenient to make the allowances by deductions from the length, each of the other dimensions being taken correctly as if the figure were perfect; but on this question each gauger may think for himself, though, as the casks at different periods often pass through different gaugers' hands in regauging, blending, racking, &c., a uniform mode is preferable, and less likely to lead to confusion.

Explanation of Plate IV.—AGBDHC, as expressed by an ellipsis, represents a section of a spheroidal cask. The same expressed by straight lines is one of the 4th variety with the same dimensions. The rules being calculated for the first, all the dimensions would be taken entire; but for the other, to allow for the difference between the figures, a portion of the length is deducted, and an imaginary spheroidal cask of shorter length, but equal content, is produced. The length of the imaginary cask is *ef*, that of the other being EF, and the whole is shown by the figure *a*G*bd*H*c*. The faint lines complete the outlines of the spheroids. WW is the surface of the liquor or wet inches; the difference of vacancy in each figure is readily discernible. GC is the diagonal, and is the same for each cask, though the difference in content is great.

The following few general directions may be taken for a guide in the matter of figure:—

Casks with a very full quarter, in which the diameter on each side of the bouge diminishes very gradually, the figure being nearly cylindrical for a long distance, and suddenly converging to form a small head, may sometimes require an addition to their lengths, as shown by the long callipers, unless the heads are very thick; for although in the spheroid the diminution in diameter is at first gradual, and becomes more rapid towards the head, yet, in such casks as we are now speaking of, the line would fall in most of its length outside the true elliptic curve, and the difference not be accounted for by the rules. Such, however, are very rare.

A straight or hollow quarter has more influence on the capacity of a cask when the difference between the head and bung is great, than when they are nearly alike. The middle frustum of a spheroid whose fixed and revolving diameters were without any great difference in length, would have the heads small and the bung large, and a rich curve for the quarter; and in this case, a straight line drawn from the chimb to the bung would cut off a large part of the figure (see Plate III., fig. 5); but a frustum of equal length, taken from a spheroid whose revolving axis was the same, but whose fixed axis was much longer than the other, would have a shape more approaching the cylindrical, and but little excess of capacity over a straight-quartered cask of the same dimensions (see Plate III., fig. 6).

Anything that alters the circular form of a cask in its section reduces its content. If, therefore, there be a great difference between the horizontal and perpendicular bung diameters, it will not do to take the bung half way between the two, as that would be too much; but an allowance must be made;—the true mean bung would be the square root of the product of the two. If the bung diameters were 20 and 25, it would be too much to take 22·5, by rather more than a 10th; but 22·4 would be near enough for practical purposes. If the diameters in the centre of the cask were 30 and 40, the mean between would be 34·7 nearly. But such differences as these only occur in casks of an oval section, which are not often met with in importation. It therefore is sufficiently accurate for practical purposes to take the mean in the usual way, by adding half the difference to the shorter dimension, giving the benefit of the half-tenth, in cases where the difference does not consist of an even number; and, where the cask is otherwise faulty, making allowances accordingly.

If, in a cask in other respects round, the bungstave alone be raised at the bunghole, so that the diameter as shown on the bung rod is in excess, the amount of error must be deducted from the dimension before comparing it with the cross. Thus, with the cross bung 33·2, and the perpendicular bung 34.4, if the bung is raised 8-10ths, the true perpendicular bung will be 33·6 and the mean 33·4. In taking the wet, if the bung rod be set to this mean, 8-10ths must be added to the wet shown, because by so much as the bungstave is raised, the rod cannot go into the liquor as it would were there no irregularity. Where the bung is depressed or flattened, the amount of depression must be added to the bung as found, and deducted from the wet inches, as the rod goes by that much too far into the cask. If, from the depression of the part, the apparent perpendicular bung is so reduced that the brass of the bung rod when set to the mean will not reach the cask, (the point of the rod being at the bottom,) the brass must be set an inch below the mean to take the wet, and the inch added thereto; then deduct the amount of error in the bung, arising from its depression, for the true wet inches. Thus, if the cross be 25·7, and the perpendicular 25, with the bung flattened 5-10ths from its proper position, the true perpendicular will be 25·5, and the mean bung 25·6; but it is evident that with the brass set to 25·6 it would not reach the bungstave by 6-10ths; it should therefore be set to the inch below, or 24·6, and then taking the wet at 1 inch more than is shown, deduct the amount to which the stave is flattened for the true wet;—thus, dipping at 24·6, say the wet is 22; add 1 inch, and it will be 23; from this deduct 5-10ths for the de-depression of the bung, and the true wet 22·5 is found.

If the bottom of the cask, that is the stave opposite the bungstave, be similarly out of place, allowances must be made accordingly,—as the bung rod will give a dimension as much over or under the true bung diameter as the stave is depressed or raised, and the calculation must be made similarly to the above. Note, however, that with a raised bottom the error is similar to the depressed bung, and vice versa, the only difference being that a fault in the bungstave does not affect the height of liquor in the cask, while the stave opposite does so to the extent of its deviation from the proper position. This is, however, frequently inconsiderable.

PARTICULARS OF AN EXPERIMENTAL EXAMINATION OF A MADEIRA PIPE, IN ILLUSTRATION OF THE PRINCIPLE OF ALLOWANCES.

A Madeira Pipe, on which some question as to accuracy of gauging had arisen, was subjected to the more tedious, but more certain operation of measurement by copper cans. Its full content was found to be 91⅜ (or 91·375) gallons; and its ullage 89⅞ (or 89·87) gallons.

The dimensions were as follow:—

			Inches.
Length by long callipers, which throw off 2 inches			47·3
Front head	21·8	Mean	21·6
Back head	21·5		
Horizontal bung, taken at inch	29·4	Mean	29·1
Perpendicular do. do.	28·9		
Wet inches			26·3

Cast out by the head rod, these dimensions would be—content 96·6, ullage 93·2;—or, in the former instance 5·3, in the latter 3·4, more than the truth.

The head of the cask was taken out, and found to average 1·5 inch in thickness; while the staves averaged 1·1 inch. It was therefore necessary that 1 inch more should be thrown off for that thickness of the heads beyond the inch for each thrown off by the long callipers. The figure was exceedingly bad; and to compensate its deficiency, a further allowance of 1·3 was made; in all, 2·3 inches off the original length. Then, as the staves were 1·1 inch thick, or 1-10th of an inch more than had been allowed in taking the bung diameter, 1-10th was deducted from that dimension, and the adjusted dimensions stood thus :

L.	H.	B.	W.	Con.	Ull.
45·0	21·6	29·0	26·3	=91⅜	88

The content found from these dimensions, by casting on the head rod agrees with the quantity as proved by actual experiment; but the ullage is 1⅞ gallon too little. This difference may be thus accounted for. The segment line on the back of the rule, by which the ullages are cast out, is calculated according to the vacancies in a spheroidal cask, and does not therefore tally with the truth, by a greater or less difference, in casks of any other figure. Now, for the same reason that casks which are straight in the quarter (as was the case in the above cask,) do not hold so much as those of a better figure, their vacancies at similar depths do not require so much liquor to fill them, and their ullage contents, therefore, are more than would be shown by the rule. Now it was proved in the present experiment that 1½ gallon filled the cask to the bung; the vacancy was therefore 1⅞ gallon less than was shown by the rules, and the actual ullage of course to the same extent greater than appeared.

It is therefore evident that in taking the wet inches of a cask of deficient figure, they must be taken at the full what they show and even occasionally presumed upon, to obtain the exact proportionate quantity.

If the Madeira Pipe under consideration be calculated at the actual dimensions as first taken, *prior* to the deduction of allowances, according to the rules given above for casks of the 2nd and 3rd varieties, (namely, by multiplying the difference of the diameters by ·64 and ·57 respectively,) the contents will be obtained as 93·36 gallons for the 2nd variety, and 89·68 for the 3rd variety. Taking the true content at 91·37, the difference of the 1st will be 1·99 in excess, of the last 1·69 in defect; so that the average is about half way between the two. This is, in fact, a practical illustration that the four varieties, as theoretically discriminated, are no guide to the gauger.

THE ARRANGEMENT OF CASKS FOR GAUGING.

It is important that before proceeding to gauge any number of casks, such arrangement of them shall be made as will facilitate the operations of the gauger.

In making up casks for gauging, they are first sorted into the separate entries to which they belong; after this, they are arranged according to their marks as to description or quality (a matter for the convenience of the merchant); the next assortment is as to size, the largest casks in each mark coming first. This being done, they are placed side by side in tiers, so as to have the front heads as nearly as possible in a line, and sufficient space between each cask to allow of free play for the cross callipers. They are to be firmly fixed, by means of *scotches* placed underneath, in a horizontal position, bung upwards, and where possible, in double rows, with the front heads towards each other, and sufficient room between the tiers, both in front and behind, to pass freely between to take the dimensions. This should be not less than 18 inches between the front heads, and 14 inches between the back heads. The whole must then be numbered in due order, reading from left to right; and on the first cask of each entry, the name of the merchant and the number of casks in such entry must be legibly written in chalk, and the word "End" on the last.

The gauger then proceeds to take the cross bung, beginning with the first cask and going through the whole series, marking the dimension on the right side of the bouge as he goes, omitting, however, the tens as unnecessary, they being, of course, suggested by the perpendicular bung, when taken. Thus, if the cross be 31·3, he would merely write 13,—that is the unit and the decimal only; where there is no decimal, as 42·0, write "2—." It is also a general practice, and perhaps more exact, to take the cross in three directions—that is, horizontally, and at as great an inclination on each side as can conveniently be managed; the mean of the three being used to work by. Having taken all the cross bungs, the next step is to take the back heads; and, beginning at the last cask, and, marking as before, only the two last figures found, he proceeds until he reaches the first cask from which he set out; when, having thus finished the preliminaries, he commences the actual gauging.

Some gaugers make a practice of taking the rest of the dimensions singly and consecutively; that is the bung dimensions of all the casks first, then all the lengths, &c.; but this is not to be recommended, as it must, of course, be impossible to remember distinctly, if at all, how the dimensions have been taken; for, though the principal allowances may be made in the length, yet there are minor particulars on each dimension that have a great influence on the total, such as whether they have been taken "easy" or "tight," and so on. It is therefore advisable in each instance to finish one cask before proceeding to another, as ensuring greater accuracy and equal rapidity.

As each dimension is taken it must be marked on the head of the cask, and this should be done in the following manner:—When the bung and wet have been taken, they must be marked near the centre of the front head, the one under the other (the right side of the cask being considered as the top, which is the position it assumes relatively to the gauger when he stoops to write); the "length" is next taken, and marked above, leaving room between it and the "bung" for the insertion of the "head," which, being the last dimension taken, leaves the head rod almost in the position for casting out the contents. In marking the figures, the decimal point is omitted, and, when no decimal occurs, a dash - marks its absence; thus, L. 497, H. 227, B. 313, W. 30-, Cont. 116, Ull. 115. (Pl. 5, fig. 4.)

In dipping for the wet inches on importation, it is usual to allow a tenth or two off what is marked on the rod, the amount of such allowance depending on the temperature, being of course less in cold, and more in warm weather. A cask gauged at a two gallon ullage, on the open quay, in frosty weather, will, when removed to the higher temperature of the vault, often show an apparent increase of a gallon, and vice versa when gauged in hot weather, when the vault is cooler. This arises from the expansion of the liquid by heat, and is more likely to occur when the ullage has been left at nearly the turn of a gallon; for, it may be remarked here, that any fraction of a gallon is not reckoned, except in removals coastwise, when 5-10ths of a gallon are taken as a full gallon, if necessary, to avoid showing a loss on transit, and in gauging Spirits in accordance with the new regulations, when the ullages are taken to the 2, 4, 6, and 8 tenths. Some gaugers talk of an allowance for the *swell of the rule*, or the displacement caused by the insertion of the bung rod into the liquor; but the necessity of such an allowance cannot be very great, when we consider that it would require $23\frac{1}{9}$ bung rods to be entirely immersed to displace a gallon, the cubic content of a bung rod of the usual dimensions being 12 inches.

After the casks have been duly gauged, the content and ullage, importer's name, and numbers of the casks, have to be "scribed" by means of an instrument for the purpose. This is intended as a means of identifying the casks when the chalk marks shall have disappeared, from damp or other causes.

Pipes, butts, hogsheads, and spirit casks of all sizes, are gauged all round,—that is to say, all the dimensions are taken and recorded; but with quarter casks and octaves generally this is only done to a few in an entry, in order to check the indication of the diagonal line, the bung rod being used to gauge them by means of its diagonal line in the following manner:—After taking the bung and wet, it is inserted in a slanting position into the cask, so that the point shall reach the inner chimb of the front head, and the mark on the diagonal line which comes to the centre of the bunghole, level with the inner part of the stave, is then noted; the same is done towards the other head, and the mean between the two is considered as the indication of the quantity. It is clear, however, that so many circumstances militate against the correct use of the diagonal, that every care must be taken to ensure accuracy; the bunghole may not be in the centre, or it may be "*depressed*" or "*cocked*," in either of which cases allowance must be made.

On quarter casks and octaves, it is only necessary to mark the bung, wet, content, and ullage, and not the length and head, except in spirit casks, which are gauged all round.

After the whole have been correctly gauged, they must be copied into the landing books under their particular entries, and according to their proper numbers and dimensions; the total ullages cast up, and the account completed, according to the established mode, which need not be described here.

BOTTLED WINES AND SPIRITS IN CASES.

As the Gauger has frequently to examine and take account of wines and spirits imported in bottle, a few words may not be out of place as to the mode of doing this.

For wines the matter is very simple. The landing books are ruled for quarts and pints, not imperial measurement, but what are termed "reputed,"—the quarts counting 6, the pints 12, and half pints 24 to the gallon.

Against the number of each case as entered must be recorded the number of bottles of either size it contains, (any unusual sizes being measured,) and the total of each size for all the cases in the entry being cast up must be divided by the number of bottles to the gallon, and the result in imperial gallons, and 6ths, 12ths, or 24ths shown in one sum; a separate total for red and white wine being, however, necessary.

In taking account of spirits, the number of bottles in each case is recorded in the first column; but, instead of being reckoned as reputed quarts, &c., actual measurements are taken to the quarter of a gill. For this purpose, after the numbers have been recorded, one case in ten is selected for measurement, the quantity found governing that of the ten from which it is taken. Where marks and qualities vary much, as many more may be selected as are found necessary for a correct average. At the same time that the bottle is being measured, the strength per cent. is taken by the hydrometer, and governs the rest in like manner.

The measurements are recorded against the number of bottles in the book, and the total in gallons and gills shown for each case, next to which is placed the strength per cent., and, in the the same line, the actual gills over or under proof. Totals are made of the number of cases, the liquid quantities, and the gills of strength, which, if O.P., are added to, and if U.P. deducted from, the liquid for the proof quantity.*

Specimen of account—

	Cases.	Bottles.		Gills.		Galls.	Gills.		U.P.	Gills U.P.
AB	1	12	ea	4¾	=	1	25	a	15.3	9
	2	12	,,	4¾	=	1	25	a	15.3	9
	2 Cases					3	18			18
							18	U.P.		
						3	0	Proof brandy, spirits not sweetened.		

In perfumed spirits, which are imported in small bottles of various sizes, the account is taken similarly, but the measurements are made to the 10th of a gill. No strength is taken, as they are not rated at the proof, but the liquid gallon.

OPERATIONS IN BOND.

After casks of wines and spirits have been gauged, they are often subjected to one or more operations before being delivered, either for home consumption on payment of the proper duties, or for exportation to some other country under legal bond.

REGAUGING.

Under all circumstances, before delivery each cask must be reëxamined and regauged, to ascertain if it be in all respects correct as entered, and this, although the merchant may have paid the full duty on the landing account. If, however, he wish to take advantage of the privilege allowed by law, of paying duty on the quantity actually in the cask at the time of delivery, by a deduction of any losses that may have occurred during the term of bonding; he takes out what is called a regauge paper for the cask or casks, which, having been duly certified by the warehousing department, is received by the gauger, and, thus authorized, he first compares the cask to see if it agrees with the description on the document, and then proceeds to regauge, both for content and ullage, noting any discrepancy he may discover in the former, or deficiency in the latter, on the regauge paper; and balancing his account to the original quantity by showing the difference under its proper column. The merchant then pays duty on the quantity thus found. If a loss of more than one gallon occurs, the Inspector's attention must be called to the cask.

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* For the mode of calculating the strengths, see page 58.

RACKING.

If a merchant wish, for convenience of sale, to have a change made in the kind of casks which contain his wine, by dividing pipes into hogsheads and quarter casks, or putting quarter casks, &c., into hogsheads or pipes, an authority must be obtained by him in the usual form from the warehouse keeper's office, with due particulars thereon. The gauger then first takes a re-gauge of the original casks, noting on the papers any difference that may appear. The division or combination is then proceeded with, and when complete, the new casks are gauged and the total balanced with the original quantity, distinguishing the alterations before and after the operation.

When large casks are divided into small ones, an apparent loss often results, as the wine that only produces an unnoticed fraction of a gallon in each of the small vessels, may, if put together, produce 1 or 2 gallons; and care must be taken by the gauger to obtain the true gauges of all the casks, so that this source of error be not increased to too great an extent, as it may easily be. For instance, a butt of sherry, containing 110 gallons, racked into four quarter casks of 28 gallons content; each of them may turn out cont. 28, ull. 27, making a total of 108 gallons ullage, and showing a loss of 2 gallons in operation; these 2 gallons being divided in each merely as an excess of half a gallon, which is not reckoned. To avoid this as much as possible, one, or even two, of the casks, if they be not of too rich content, may be filled to the bung, and the others left at the exact gauge, so that there may be two each 28 cont., 27 ull., and two each 28 full, equal to the original gauge. This, of course, depends, to some extent, on the terms under which the operation is requested.

It may be well here to note that, from the mode in which casks are gauged on importation, they may not unfrequently have more in them than is charged, to the extent sometimes of nearly two gallons, a circumstance which must be taken into calculation in any of the operations now under consideration. Thus, a cask gauged at 56 gallons content, may have a capacity of 56·8, the fraction being thrown aside; this same cask in the dip may show 2·7 dry inches, which would be reckoned as a vacancy of three gallons, although only a trifle below a two gallon ullage. The cask then would be called 56 content, 53 ullage, when, from the causes just named, there would be nearly 2 gallons more in it; thus, a three gallon vacancy on a cask 56·8 would leave 53·8; but as the vacancy in this instance is only just over two gallons, say 2·1, it would leave a fraction of ·9 in the ullage unaccounted for, to be added to this, and the real ullage would therefore be 54·7, or 1·7 gallon more than charged. In changing the size of the packages, therefore, this may often lead to error, unless it be carefully noted by the gauger, and proper allowances made. Still, it often happens that we cannot quite meet this source of error, and in racking wine from larger into smaller packages losses will sometimes occur; while, on the contrary, in racking from smaller into larger increases sometimes appear. Such alterations are treated as "loss or gain in operation" in making up the account, and distinguished from any alteration prior to operation.

VATTING AND BLENDING.

Vatting is an operation in which large quantities of wines or spirits are mixed in vats to obtain an equality of character. After being so mixed, they are returned into the original casks, or others that may have been provided for the purpose.

The gauger's duty is to check the quantities in the casks before starting them into the vat, and to record any difference in strength or quantity. The strengths of spirits may be taken from each cask separately, and the total difference thus estimated; or the spirits may be first started into the vat, and the average strength estimated from a sample taken from the bulk. The former is the preferable plan, as it takes some time before the whole contents of the vat are so thoroughly mixed as to be of uniform strength; for, from the difference of specific gravity, the strongest spirit will for some time keep near the top, and the weakest at the bottom, until, by stirring and mixing, a complete union is effected. The total loss on the strength and ullage thus obtained is the total loss *prior*, and is to be shown separately.

Colouring or Reducing may then be proceeded with according to the terms under which the operation has been allowed by the Customs, and when complete, and the goods are being drawn off, a sample must be taken for the vat strength; and on gauging the quantities after being drawn off into their proper casks, the account must be made up shewing the total loss or other alteration, and balancing with the original quantity, distinguishing the alterations *prior* to those *after* operation. In fining spirits, either by the ordinary wine-finings or milk, little or no appreciable alteration in strength is produced; but in adding pineapple juice to rum, (which is sometimes permitted for exportation only,) the action of the Hydrometer is interfered with, and there is an apparent reduction in strength to a much greater extent than really occurs.

Blending is a similar operation to Vatting, only on a smaller scale, being limited to a few casks of one description of wine, which may be mixed by being drawn off altogether into a larger cask, and returned into the originals or others provided; or else, by drawing off from each cask a certain proportion, and supplying the vacancy from the others.

In Vatting and Blending, the import marks and brands must be removed, and the letter V or B substituted, unless the mixed wines are all of the same marks and brands, in which case they are allowed to remain.

REDUCING.

Reducing is an operation whereby the strengths of spirits are reduced by the addition of water; this operation is in principle the same as the rest. The quantities and strengths are tried prior to the operation, and any alteration shown; the required quantity of water is then added, and the resulting liquid quantity and strength balanced with the original in the usual way.

FORTIFYING.

Fortifying is the addition of spirit to wines to increase their strength, which is allowed to a certain extent, regulated by orders of the Board of Customs; the total strength after the operation must not exceed 40 per cent. of proof spirit.

BOTTLING.

In bottling wines and spirits, the alterations in the casks prior are to be shown in the bottling book, as in other reëxaminations. The contents of six of the bottles to be used are then to be measured, and the rest are taken accordingly. In case the number to be bottled at one time is large, others should be similarly measured, and the average of the various measurements taken for the whole. They must be packed into cases containing not less than 1 doz. reputed quarts, or 2 doz. reputed pints, and the whole exported. Duty may be paid for home consumption on any ullage left in the cask, but not on any remnants bottled. The account must be made up as for imported cases.

OF THE STRENGTHS OF SPIRITS, AND THE USE OF THE HYDROMETER, WITH A BRIEF EXPLANATION OF THE PRINCIPLES OF ITS ACTION.

Spirits are not only gauged as wines are for their liquid quantity, but have to undergo a subsequent operation with a view to ascertain their strength, that is, the relative proportion it bears to a fixed degree called "proof."

Proof spirit, according to careful experiments of Mr. Drinkwater, is composed of 100 parts by measure of alcohol, with

81·82 of water, at the temperature of 60° F.; the specific gravity of the mixture when fully combined, is ·919, and its bulk 175·25, or 6·57 less than the total bulk of the substances when separate.

When spirits are of greater strength they are called "over proof," and when of less strength "under proof," the charge for duty being always reckoned on the number of "proof" gallons and tenths equal to the quantity at the strength found.

In order to ascertain this proportion correctly, advantage is taken of the difference of specific gravity between water and alcohol, and of the intermediate admixtures of either which constitute the varying strength of spirits as usually met with.

By specific gravity is merely meant the proportionate weights of equal bulks of different substances, and is generally expressed with relation to one particular substance, which is taken as the unit of comparison. For this purpose any substance may be selected; but, as pure water possesses more convenient qualities than most other materials, it is generally used, and in expressing the specific gravity of a substance in figures, it implies that if a certain bulk of pure water weigh 1, the same bulk of the substances will weigh as many parts as the figures express. Thus, if a bottle be constructed so as to hold exactly 1,000 grains of pure water at 51° F., and if this bottle be filled with proof spirit, the latter will be found to weigh 923 grains,—or taking water as 1, proof spirits will be 0·923.

When water and alcohol are mixed, a specific gravity intermediate between the extremes is obtained, being greater or less in proportion as the former or the latter is in excess. But there is a peculiarity in the union of these two substances that requires to be noticed. It may perhaps be imagined that if equal quantities of each were to be blended together, the resulting mixture would be of an exactly medium gravity; this, however, is not the case,—for alcohol and water have such a strong tendency to unite, that a condensation takes place, and the bulk of the mixture is less than that of the two ingredients before combination, consequently its specific gravity is increased;

still it is always less than water, and greater than pure alcohol, whatever the amount of either substance there be in it.*

To weigh a bottle full of the mixture, in order to assess its specific gravity, would be tedious as applied to the number of operations which it is necessary to perform in the Customs, as each individual cask of spirits that is imported has its strength tried; and this, not only on importation, but on delivery, or on the performance of any operation, as "racking," "blending," drawing off to fortify," &c., &c., this being rendered necessary from the loss of strength that often occurs by evaporation or other causes. In order, then, to facilitate the matter, advantage is taken of the property which liquids have of supporting floating bodies in the proportion of their densities.

A ship will sink deeper in fresh water than in salt water, the salt in solution rendering the water specifically heavier; and any one who has bathed in fresh and salt water must have observed the difference of sustaining power. An egg that will sink in fresh water will float in a pickling brine.

The reason, briefly stated, for this is as follows:—Every body, immersed in a fluid, displaces a quantity of the fluid equal to its bulk, receiving at the same time from the surrounding portion a pressure equal to the weight of that displaced, and tending, to that exact amount, to support it. If the displaced fluid be less in weight than the body immersed, the body sinks with a force equal to the difference; thus, a body weighing 2½ lbs., which displaces 2 lbs. of water when immersed, will sink with a force of ½ lb., the rest of the weight being supported by the water; such a body would therefore only weigh ½ lb. when placed in the water, and consequently, taking water as 1·0, the specific gravity of such a body would be 1·25. If, again, a body immersed in a liquid displaces exactly its own weight, it will float indifferently in any part of the liquid beneath the surface, and will of course be of the same specific gravity. But if the liquid displaced by the immersed body be greater than the weight of such body, a force upwards is exerted to the amount of the difference, and the body will float with only so much of its bulk beneath the surface as will displace liquid equal to its entire weight.

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* When mixed with water a considerable amount of heat is evolved, and a remarkable contraction in volume is observed; these effects being greatest with 54 per cent. of alcohol and 46 of water, and thence decreasing with a greater proportion of water. With 90 per cent of water, the condensation is 1·94 per cent. of the volume; for 80 per cent., 2·87; for 70 per cent., 3·44; for 60 per cent., 3·73; for 40 per cent., 3·44; for 30 per cent., 2·72; for 20 per cent., 1·72; for 10 per cent., 0·72.—Vide *Ure's Dict.*, "*Alcohol.*"

Thus, take a piece of wood of a bulk of 301 cubic inches, loaded with lead till it exactly weighs 10 lbs., and immerse it in a vessel of water; it will float to the surface, and if the line where the water comes round it when it is at rest be carefully observed, and the solid contents of the portion above the surface estimated, it will be found to be 23·726 cubic inches; that is to say, it will have displaced as many cubic inches of water as are equal to 10 lbs. weight, or 1 imperial gallon, equal to 277·274 cubic inches; which, deducted from 301, will leave 23·726, equal to the bulk above the surface. If, now, this same piece of wood be immersed in proof spirit, it will sink so much lower that only 0·62 cubic inches will be left above the surface. The immersion then in the water was 277·274, but in the spirit it was 300·38; or, if the first be taken as 12, the latter will be 13, proof spirit being $\frac{12}{13}$ of the weight of distilled water, as fixed by Act of Parliament; or, water being 1, the specific gravity of proof spirit is ·923.

The Hydrometer is nothing more than an instrument constructed on this principle, but so formed that the depth of its immersion in liquids of various densities may be readily observed and estimated. There are many such instruments, of different forms, and greater or less delicacy. Of these, Sikes's Hydrometer is the one used generally for revenue purposes being especially calculated for thus estimating the strength of spirits.

Sikes's Hydrometer, Pl. V., fig. 5, consists of a hollow brass ball, commonly $1\frac{6}{10}$ inch in diameter, into which is inserted, by its smaller end, a conical shaped stem, having, at the other end, a small loaded bulb, which is much heavier, bulk for bulk, than the rest of the instrument, and is intended by its weight to cause the whole so to float that a brass rod or stem, 3$\frac{4}{10}$ inches in length, which is inserted on the opposite side of the brass ball, shall maintain a perpendicular position. This stem is divided into a scale of 10 equal parts, which are again subdivided into 5, each of which represents 2 tenths. There are, also, a series of weights so shaped as to be readily attached to the lower stem, and numbered respectively 10 to 90, each *ten* corresponding to the whole 10 divisions on the stem, and being equivalent, if the instrument be floating with the lowest division of the scale on a level with the liquid, to sink it till the highest division reaches the same position. In alcohol 70 per cent. over proof at a temperature of 47 Fahr., the instrument, without any weight attached, will sink to the highest line on the scale, marked 0; and in distilled water, of the same temperature, it will, with the weight 90 attached, float with division 10 on a level with the surface. This is, therefore, equivalent to dividing the interval between the strongest distilled alcohol and pure water into 500 equal parts, and any strength can be calculated with a degree of accuracy equal to one such division.

The temperature of a liquid influences its gravity. Liquids expand by heat and contract by cold, consequently their specific gravities are increased by the latter and diminished by the former. The temperature, therefore, is an important element in the estimation of the strengths of spirits. Were it not taken into account, a weak spirit tested in warm weather would appear stronger than one of really greater strength tried in the winter. In taking strengths of spirits, great care must be observed in regard to the temperature—not only of the spirits, but of the instruments themselves; and if, on taking the Thermometer from the box where it has been kept with the Hydrometer, and immersing it in the spirit, it shows a tendency to rise or fall, the Hydrometer should be left in the spirit till it has had sufficient time to acquire the same temperature. The Hydrometer warm, and the liquor cold, will show an inferior degree of strength to the reality, and vice versa.

To meet these changes calculations have been made, and a set of tables produced, in which the differences of temperature and indications on the stem of the Hydrometer are taken into account, and too much care can scarcely be taken in having all these points correctly observed.

In trying the strengths of spirits for revenue purposes, it rarely happens that the temperatures of the samples and the instruments coincide at first. The samples may be taken from the quay in frosty weather, or in the bright sunshine of summer, and thus be either far colder or hotter than the place and apparatus in and by which they are tested; while, sometimes, samples follow each other from the vaults and the quays, each in succession differing from the rest. Sufficient time should therefore be given for the mercury in the Thermometer to rest; and both Hydrometer and Thermometer should be put in the sample at the same time, that they may equalize in temperature.

Although the sensibility of Sykes's Hydrometer is inferior to many other kinds used in scientific investigations, it is still excessively delicate in its indications, being sensible to one five-hundredth part of the difference between the gravities of water and alcohol, or one sixty-five hundredth part of its own weight of water. It is therefore needful to be cautious and gentle in handling it. The slightest bruise in the hollow ball, even though imperceptible to the eye, will affect its accuracy; and the incrustation which ensues after its use in brown brandy, from a deposition of the coloring matter, also renders it erroneous. It ought, also, not to be left exposed to the air while wet, during its use, as the rapid evaporation of the spirit induces a great degree of cold, contracting the bulk of the instrument, and causing it to sink deeper than it should. This source of error may be avoided by keeping it constantly immersed during the intervals of using it, or transferring it immediately to the next sample to be tried.

As the indications of the Hydrometer depend on the specific gravity of the liquids, it is obvious that if this be altered by any other means than the admixture of water and alcohol, these indications are not true as considered relatively to those two ingredients. Thus, if any matter be held in solution by the spirit, by which its specific gravity is increased, the Hydrometer would float at a position indicative of a less strength than the reality. Coloring matter has this effect; and of two samples of spirits of equal strength, the one colored and the other plain, the former would appear the weaker. This source of error is not taken note of in the case of colored spirits, the difference being generally so slight as to be practically unimportant; but when sweetened, the specific gravity is so increased that not even an approximation can be made to the truth, which could only be discovered by a careful distillation.

In order to guard as far as possible against error, the Hydrometer should occasionally be tested as to its accuracy, which may be done by placing the weight 60 on the bottom stem, and immersing it in proof spirit at the temperature of 51°, when the instrument will sink to a line on the side of the stem marked for this purpose, and the further addition of a square brass cap which accompanies it will sink it to the same point in distilled water of the same temperature. This brass cap is $\frac{1}{13}$ of the weight of the instrument with the weight 60 attached, so that it proves what we remarked above, that proof spirit is $\frac{12}{13}$ of the weight of of an equal bulk of distilled water at the same temperature; that is, 12 gallons of distilled water will balance 13 gallons of proof spirit. The weight, therefore, of 1 gallon of proof spirit is 9·23 lbs., water being 10 lbs.

In taking the strength of a sample of spirit a cylindrical glass vessel is used, of sufficient diameter for the Hydrometer to float easily without touching the sides, and deep enough when full of liquid to immerse the whole instrument. This vessel, being filled with the spirit to be tried, the Hydrometer is placed in it with one of the weights added which is found on trial to cause it to float at an intermediate point on the scale. The Thermometer is then placed in the liquid, so that its weight keeps the Hydrometer at the bottom. As long as the mercury shows any inclination to move, it must be left; when still, its height must be noted and marked down; and, on its removal, the Hydrometer will settle itself with some degree on the stem level with the surface, which must also be noted, being read, where the transparency of the liquor will allow, from beneath. On reference, then, to the tables, under the particular temperature, and in a line with the indication, will be found the strength per cent. over or under the point called proof. When a number of samples is being tried at once, the whole having been drawn from casks in the same entry and under the same circumstances as to temperature, it is deemed sufficient to take the temperature of the first to govern the lot, with an occasional check by the thermometer when the number is large.

Suppose the temperature to be 54°, and that the weight 40 placed on the instrument sinks the upper stem so that the division 4 rests exactly on a level with the surface of the liquor; the indication will be 44·0; and upon referring to the table, it will be found that the strength is 22·9 per cent. over proof. If, however, any of the subdivisions stand nearer the surface, as for instance, ·2, the indication will be 44·2, and the per centage over proof will be found by the table to be 22·6; and so on to any other division, or with any other weight or temperature. When the division is not exactly on the level of the liquid, take the nearest above or below, and proceed as before.

The strength per cent. thus found must be multiplied into the quantity of liquid, and then divided by 100, which is merely equivalent to removing the decimal point two places to the left. Thus, taking the gauged quantity at 119 gallons, and the strength per cent. 22·9 O.P.; 119×22·9=27·251 O.P., which, added to the quantity, 119+27·251=146·251 proof gallons; or, the actual liquid quantity there would be if, by the addition of water, the strength of the whole were reduced to proof. The over proof quantity does not express the bulk of water, the addition of which would reduce the spirit to proof, because water to that quantity added would neither increase the total bulk to the same amount, in consequence of the condensation that takes place when spirit and water are mixed, nor reduce the strength in the same proportion; but, it expresses the total additional bulk the liquid would have when exactly reduced to proof, at a temperature of 62° F., the difference between the over proof and the quantity of water necessary being the amount of actual condensation.

By a recent General Order of the Board of Customs, consequent on some new regulations of the Government for the purpose of assimilating the practice of the Excise and Customs in their mode of levying duties on spirits in casks, the fractional parts, both of the ullage and strength, are to be charged.

The casks are, as usual, to be gauged to the gallon only on the content, and the wet inches taken in the ordinary manner, making the proper allowance for the variations of temperature; but, instead of taking the ullage to the gallon, it is to be charged in all quarter casks and casks of smaller size, on every 2 tenths of a gallon, as cast out on the back of the head rod; viz., 2, 4, 6, and 8 tenths, or the full gallon, as the case may be. In all casks larger than quarter casks, the ullage is to be taken to the half gallon only, unless it do not exceed 30 gallons, when it is to be reckoned to the 2 tenths, whatever the size of the containing vessel may be.

In casting out the strengths, the per centage strength is to be multiplied into the liquid quantity, and divided by 100, and, when over proof, taken to the first decimal place to be added for the proof gallons; but when under proof, to the second place of decimals to be deducted. The reason of this being, that the advantage of the fraction may tell in favor of the merchant.

As, for example, a quarter cask with an ullage quantity of 29·6 gallons, at a per centage strength of 14·7 over proof or under proof.

29·6 gallons liquid
14·7 strength per cent.

2072
1184
296

4·3512 product, with decimal point removed two places to the left, to indicate its being divided by 100.

Now, discarding all but the first two places of decimals, we have 4·35 for the proportionate quantity of over or under proof on 29·6 gallons, at 14·7 per cent. If we take the figures as "over proof," we shall have to add them to the liquid quantity; if as "under proof," to deduct them, to obtain the actual proof gallons. In the former case, the second figure in the decimals will make no difference; it may therefore be omitted. In the latter, it will invariably cause a diminution in the proof quantity to the amount of one tenth; and it is to be retained to give the merchant the benefit to that extent. The actual underproof may therefore be expressed as one tenth more whenever the second decimal is 1 and upwards; thus, 4·35 U.P. may be taken as 4·4 U.P., as the resulting quantity will be the same when either is deducted; and in making up accounts comprising several casks, the total of the underproofs deducted from the total liquid gallons will be in this case the same as if the actual proof quantities of each were added together.

EXAMPLE:

a.	*b.*	*c.*	*d.*
29·6	29·6	29·6	29·6
4·35 O.P.	4·3 O.P.	4·35 U.P.	4·4 U.P.
33·95 Proof	33·9 Proof	25·25 Proof	25·2 Proof

As the proof quantities are only charged to the tenth of a gallon, or the first decimal place, it will be seen that the results in Ex. *a* and *b* for overproof are practically the same; and in Ex. *c* and *d* for underproof also.

Another mode of working out the proof quantities is sometimes useful; it consists in multiplying the liquid quantity by the overproof added to 100, or the underproof deducted from 100, and the quotient gives the result in proof gallons. Thus, with the same quantities as the previous example:

29·6 O.P.	29·6 U.P.
114·7=100+14·7	85·3=100—14·7
2072	888
1184	1480
296	2368
296	25·2488 Proof.
33·9512 Proof.	

The results, taking the first decimal only, are identical with those by the other mode.

In casting out the strengths of spirits in bottles, the strength per cent. multiplied into the number of gills, and the product divided by 100, is the total over or under proof;—if the decimal be 0·5 or upwards, it is charged as one gill; if less, it is not reckoned. Thus, 1 gall., 31 gills, at 14·9 U.P., and the same at 14·0 U.P.

63 gills	63 gills
14·9	14
567	252
252	63
63	8·82=9 gills U.P.
9·387=9 gills U.P.	

Till lately, the practice has always been to charge the proof gallon when the decimal parts were 0·84 and upwards, and the strengths could then be cast out on the back of the rule in all cases, except where that point was approached so closely as to make it necessary to work it in figures in order to be certain. Now, however, the whole should be worked out with the pen; for, although in many instances it may be done on the rule with sufficient accuracy in low strengths, yet even here it would be so frequently necessary, in order to be correct, to test by figures, that it is probable more time would be lost than gained by using the back of the head rod for that purpose.

In using the back of the head rod to cast out strengths, the operation is very simple, and is done in the following manner:—

Set the strength per cent. on the lower line of the slide to 100 on the lower line of the rule; then, underneath the liquid quantity as found on the upper line of the rule, will be the proof gallons on the upper line of the slide, which will be over or under proof, as the case may be. The divisions on the back of the rule and slide may be read as of any value decimally, according to their relation to the question; thus, 40 may be read as 400, as 4, as 0.4, or 0·04, &c.; and 4·56 as 45·6, 0·456, or 456, &c., the divisions bearing always the same relative proportion to the unit of comparison.

OF THE VARIOUS KINDS OF CASKS IMPORTED, AND HINTS AS TO THEIR AVERAGE MODE OF TREATMENT. ALSO, SOME REMARKS ON GAUGING BY STANDARDS, AND THE CALCULATION OF ULLAGES BY THE DRY INCHES.

It will be necessary for the Gauger, as he acquires experience, to verify these remarks for himself, and not to place implicit reliance upon them in all instances; they are intended merely as suggestions, not as positive rules.

PORT PIPES.—These are large, fine casks, of good figure and thin wood, and are frequently of the first variety, or a close approximation thereto, in which case they may be safely gauged at their exact dimeusions; indeed, instances are not few where, even thus treated, casks of very rich full quarter and thin timber have been found to contain more than they were gauged at, to the extent of two gallons and upwards. Some, however, are inferior in figure, and from 5 tenths to 8 tenths, or even more, are required off the length. From the practice the Portuguese coopers have of loading their casks with wooden hoops between the iron ones, it is difficult, on a superficial observation, to detect little errors; but by practice the eye becomes enabled to trace the line of curvature by means of the iron hoops, which, being regular in their thickness, do not mislead it to the extent the others are apt to do. The direction of the ends of the staves is some guide, as in casks of good figure they incline inwards more than where the figure is bad. Cross and dip at 1 inch (that is, take the horizontal and perpendicular bungs with an allowance of 1 inch for thickness of wood). Contents from 116 to 120 gallons.

PORT HOGSHEADS are of the same variety of figure, but are shorter frustums of a spheroid, and have but little difference between the length and bung. They may be taken at their full dimensions, and in good figures with thin heads a tenth or two may sometimes be added to the length as shown by the callipers, which, as they allow an inch at each end, throw off in such case more than is necessary. Cross and dip at $\frac{3}{4}$ inch, and if very thin, a tenth may be added to the mean bung. Contents from 57 to 60 gallons.

Port Quarter Casks are also good figures, and gauge well by the diagonal. When gauged all round, the bung may generally be taken at half inch wood, and 3 or 4 tenths added to the length. Contents average 30 gallons.

Lisbon Pipes appear to be better figures than they really are, partly from the deceptive effects of the wood hoops, and partly from their thickness in the quarter and head. Take the bung at 1 inch. The heads are very irregular in thickness, varying often from 1 inch to 2 inches in pieces side by side, on an average from 1·2 to 1·8 inches. Allow on length from 1 inch to 1·8 inch. Contents from 116 to 122 gallons.

Lisbon Hogsheads.—There is a short description of this cask, of very good capacity, the staves thin, but the heads thick and irregular, which latter may be perceived by feeling lightly the inner surface of the head with the point of the bung rod. All the length may be taken, and cross and dip at ¾ inch. A long description of this cask must have from 4 to 8 tenths off the length. Contents from 58 to 62 gallons.

Lisbon Quarter Casks.—The diagonal of these generally exceeds the true content by 1 or 2 gallons, from their shortness. In gauging all round, add 1 or 2 tenths to the mean bung, taken at ¾ inch, and take all the length. Contents from 28 to 30 galls.

Sherry Butts are mostly clean, well-made casks, but inferior in figure to Port pipes, besides having thicker wood, especially in the heads. They are shorter in proportion, and have larger bung and head diameters, with a straighter quarter. They hold from a gallon to a gallon and a half less than they would if of spheroidal figure. The heads are generally 1·1 inch to 1·3 inch thick, and an allowance of 4 to 7 tenths is required for figure; so that the total allowance may be put at from 6 to 11 tenths. Cross and dip at 1 inch; and if the thickness be greater, make allowance accordingly. Contents from 107 to 114 gallons.

Sherry Hogsheads are good casks, of similar figure to the butts; they are often of thick wood, but most generally about

¾ inch, and from that to 9 tenths. The general allowance on the length for figure, &c., is from 2 to 5 tenths. Cross and dip at ¾ inch, and, when thick, allow 1 or 2 tenths on the mean bung, as may be necessary. Contents from 54 to 59 gallons.

Sherry Quarter Casks vary much in figure; some can be correctly gauged by the diagonal, while others show on the diagonal from 1½ to 2 gallons more than they contain. These latter ones are short, dumpy casks, and where there are many in an entry they can be gauged with tolerable accuracy by the diagonal, if checked occasionally by going over one or two with all the rules, and throwing off from the diagonal shown the amount of estimated excess. Cross and dip at ¾ inch, adding a tenth to the mean bung if thin, and take all the length. Contents from 27 to 29 gallons.

Spanish Red Pipes.—It is difficult to fix a rule for these casks, as they vary so much. From 5 tenths to 1 inch is about an average of the allowance on the length; cross and dip at 1 inch. Contents from 98 to 105 gallons.

Spanish Red Hogsheads.—The figure of these is generally fair, and they are more easily treated than the pipes. Take the bung at 1 inch, and allow from 2 to 5 tenths on the length. Contents from 48 to 50 gallons.

Rhenish Four-Aums, or Aulms are cylindrical casks, of thick wood, and want little or no allowance except for the thickness of the heads, say from 4 to 6 tenths. The bung to be taken at 1 inch. The contents average 120 gallons.

Rhenish Two-Aums are similar casks. Take all the length, and cross and dip at 1 inch. Contents from 60 to 62 gallons.

Rhenish Aums.—The diagonal exceeds the true content. Gauged all round, they may be averaged at from 8 to 9 tenths thick. Contents 30 to 32 gallons.

Madeira Pipes are well-made, clean casks, but so thick, and of such straight quarter as to require large deductions. Cross and dip at 1 inch, and where the thickness exceeds make extra allowance. Allow on the length from 1·8 to 2·2 inches, or even more, in extreme cases. Take the wet inches very tight. In most instances it would be well to dip at 1·1 inch or 1·2 inch for the wet, where the casks are thick, to meet the deficiency of figure, as a gallon will generally fill a two gallon ullage. Contents from 90 to 95 gallons.

Madeira Hogsheads are similar in character to pipes. Allow from 5 tenths to 1 inch on the length, and cross and dip at 1 inch. Contents from 44 to 49 gallons.

Madeira Quarter Casks may be gauged by the diagonal, which shows rich on them; but its indication must be carefully checked by occasionally gauging one all round; in which case, take them as being 9 tenths thick. Cross and dip at ¾ inch. Contents from 22 to 24 gallons.

Teneriffe Pipes are thick casks of bad figure, and great length in proportion to their other dimensions. They require from 1 inch to 1·5 off their lengths. Cross and dip at 1 inch, and take the wet inches tight. Contents from 96 to 103 gallons.

Teneriffe Hogsheads are also thick and of bad figure. Cross and dip at 1 inch, adding 1 or 2 tenths, as may be necessary, to the mean; and allow from 4 to 9 tenths on the length. Contents from 48 to 50 gallons.

Teneriffe Quarter Casks may be gauged by the diagonal, which shows rich on them, as the straightness of the quarter causes a deficiency in the containing power without altering the diagonal line. Contents from 24 to 26 gallons.

Marsala Pipes are long casks, of bad figure, often hollow in the quarter; they are also frequently of thicker wood in the quarter than would appear from the chimb or bunghole. Cross and dip at 1 inch, and throw off from 8 tenths to 1·2 inch on the length. The heads are mostly thick, Contents from 92 to 96 gallons.

Marsala Hogsheads are similar. Cross and dip at 1 inch, and add 2 tenths to the mean, as the staves average 8 tenths. Allow from 4 tenths to 9 tenths in the length. Contents from 45 to 48 gallons.

Marsala Quarter Casks diagonal, in most cases truly. Contents from 22 to 24 gallons.

CLARET HOGSHEADS are very nearly cylindrical in figure. They vary much in thickness, though the average is about 8 tenths. The heads are mostly thin, now and then extremely so. As a general rule, treat at 8 tenths, by crossing and dipping at 1 inch, and adding 2 tenths to the mean bung; but in exceptional cases, treat according to the actual thickness; nevertheless, always cross at 1 inch, as you will not then be in doubt which you have done, as may be the case if no regular rule be followed. Take all the length; in some instances, when the heads are thin a slight addition may be made. Contents from 45 to 50 gallons.

BURGUNDY HOGSHEADS may be treated similarly to Claret Hogsheads, which they resemble.

There are several varieties of FRENCH PIPES imported; some very short, with large bung and head diameters, and very rough make. Cross and dip at 1 inch, and make a small allowance 2 to 5 tenths in the length. Others are very thin, full in the quarter, and long, and must be gauged tightly, taking all you can get, and sometimes presuming on the dimensions, especially if the cask be of nearly equal diameter for some distance on each side of the bung, diminishing towards the head abruptly afterwards. Others, again, though thin, are of so bad a figure, that it is necessary to make very great allowance on both bung and length, to the amount of 3 or 4 gallons, say 1·2 to 1·6 inch on length.

CAPE PIPES have some similarity of character to Marsala casks, but are rather longer. Take the bung at 1 inch, and allow from 6 tenths to 1·2 inch on the length. Contents from 95 to 100 gallons.

CAPE HOGSHEADS.—Take the bung at 1 inch, and allow 4 to 8 tenths on the length. Contents from 56 to 65 gallons.

CAPE QUARTER CASKS are short; may be gauged by diagonal, with occasional check by the other dimensions. Contents from 30 to 34 gallons.

CHARENTE BRANDY PUNCHEONS are fine, well-made, thin casks, of good figure, and may be taken tight in all their dimensions, as they rarely require allowances—at the utmost 2 to 3 tenths on the length; if very short, say 43·6 long, 1 or 2 tenths may be added. They approach the cylindrical figure, there being but small difference between the head and bung diameters. Cross and dip at 1 inch, and, if thin, add 1 or 2 tenths to the mean. Contents from 112 to 120 gallons.

Charente Brandy Hogsheads are also thin, good figure casks, and may be gauged tight; some short casks requiring the addition of a tenth or two, as the heads are mostly thin; now and then an allowance has to be made, but very rarely. Cross and dip at ¾ inch. Contents from 57 to 60 gallons.

Charente Brandy Quarter Casks are always gauged in all their dimensions. Add 2 tenths to the bung, taken at ¾ inch, and about 4 tenths to the length, taking the wet tight, especially when the content is rich. Content from 28 to 32 gallons.

Bordeaux Brandy Puncheons.—Take the bung at 1 inch, and allow 4 to 7 tenths on the length. Contents from 112 to 120 gallons.

Bordeaux Brandy Hogsheads may be treated as Charentes generally, but some require 2 or 3 tenths off the length. They are rather larger than Charente Hogsheads.

Bordeaux Brandy Quarters, treat as Charentes.

Geneva Puncheons.—Take the bung at 1 inch, and with care, as they are frequently cocked. Allow on the length from 3 to 9 tenths. Contents from 98 to 112 gallons.

Geneva Hogsheads.—Cross and dip at 1 inch as a general rule, adding 1 or 2 tenths to the mean, and allow 2 or 3 tenths tenths on the length. Contents 58 to 60 gallons.

Geneva Quarter Casks.—Cross and dip at ¾ inch, and add 2 to 4 tenths to the length. Contents 30 to 33 gallons.

Rum Puncheons—Of English make, from the West Indies, are stout casks of good figure, and require no allowance for figure; from 2 to 3 tenths for thickness may be allowed sometimes. Other casks made in the Colonies are more irregular, and require from 4 to 5 tenths on the length. Take the bung easy at 1 inch. Contents 90 to 102 gallons.

Rum Hogsheads require no allowance generally. Take the bung at 1 inch. Contents 53 to 58.

Some Hogsheads from Penang having thick heads, often of teak wood, require 7 to 8 tenths off the length.

STANDARDS.

When casks run very similar in figure and thickness, and vary but slightly in dimensions, they may be gauged by what is called a Standard. This, however, should only be done by the experienced Gauger, as in other hands there is great liability to error, and indeed at most times it is preferable to cast out the contents of each cask on the head rod.

A Standard is an assumed set of dimensions, casting exactly to a certain gauge; and from this, by comparison, the contents of the casks are calculated as their dimensions are taken, without being cast out on the head rod. The principle is founded on the relative proportion to a gallon which $\frac{1}{10}$ of an inch has on the various dimensions, and which within a small range has but little appreciable variation. There is, however, a degree of uncertainty about it that renders its use limited, and often unadvisable: indeed, with some classes of casks it is impracticable.

Port and Brandy Casks are more readily gauged by Standard than perhaps any other, and we will now, therefore, confine ourselves to them, merely premising that the gauger can always select a standard for himself to work by in any other cases where he may find it advantageous.

The Standard most frequently used for gauging Port pipes is

L.	H.	B.	Cont.
497	227	313=116 gallons.	

Now, it is found in practice that 4 tenths on either the head or length are about equal to 1 gallon, while on the bung only 2 tenths are required to make up the same quantity. It follows that each tenth on the head and length equals 1 quart, and each tenth on the bung equals 2 quarts. If, then, in taking the dimensions of a

Port pipe, we found L. 50, H. 226, B. 314, on comparing each of these dimensions with the above Standard, we should find 3 tenths more on the length, 1 tenth less on the head, and 1 tenth (equal to 2 tenths) more on the bung, which would be in all 5 quarts more than the Standard on two dimensions, and 1 quart less on the third; total, 1 gallon more than the Standard; —so that the cask would gauge 117 gallons. This operation is very simply performed if, as each dimension is taken, it be compared with the same dimension of the Standard in the mind, and the amount added to or deducted from the 116 gallons.

The following will show the working of the principle:—

L.	H.	B.	Cont.	Difference.
497	227	313	=116	*l.* *h.* *b.* *Gall.*
494	229	314	=116	$(-\frac{3}{10}+\frac{2}{10}+\frac{2}{10}=+\frac{1}{4})$
50-	226	313	=116	$(+\frac{3}{10}-\frac{1}{10}\ \circ\ =+\frac{1}{2})$
501	227	314	=117	$(+\frac{4}{10}\ \circ\ +\frac{2}{15}=+1\frac{1}{2})$
502	228	315	=118	$(+\frac{5}{10}+\frac{1}{10}+\frac{4}{10}=+2\frac{1}{2})$

A Standard for Brandy Hogsheads is

L.	H.	B.	Cont.
34-	221	257	=58 gallons.

In this instance 3 tenths on the bung, 6 tenths on the length, and 6 tenths on the head, are each equal to 1 gallon. Thus:—

L.	H.	B.	Cont.	*l.* *h.* *b.* *Gall.*
34-	223	259	=59	$(\ \circ\ +\frac{2}{10}+\frac{2}{10}=+1)$
336	221	256	=57	$(-\frac{4}{10}\ \circ\ -\frac{1}{10}=-1)$

In all these, if the principal increase occur in the bung dimension, the value will be greater than if on the length or head, together or separately.

As a rule, when gauging by Standard, cast out the contents on the head rod if the difference approach closely to the estimated integral gallon.

The following is a table of Standards for a few varieties of casks, which may be occasionally found useful:—

	Dimensions.							
Cask.	L.	H.	B.	Cont.		L.	H.	B.
Port Pipe.	497	227	313	116	Amount on each dim. equal to 1 gall.	04	0·4	0·2
„ Hogshead .	29-	23-	282	58		0·6	0·8	0·3
Sherry Butt .	42-	259	328	112		0·4	0·4	0·2
„ Hogshead	316	215	266	56		0·5	0·6	0·3
„ „	322	213	267	57		„	„	„
„ „	312	212	27-	56		„	„	„
„ „	317	212	27-	57		„	„	„
Claret Hogshead*	29-	228	252	49		0·6	0·7	0·3
Rum Puncheon .	34-	27-	32-	89		0·4	0·5	0·2
„ Hogshead*	315	215	26-	54		0·6	0·8	0·3
Brandy Puncheon	46-	265	31-	114		0·4	0·4	0·2
„ Hogshead	34-	221	257	58		0.6	0·6	0·3
„ Qr. Cask	293	173	203	31		1·0	1·0	0·5
Gin Hogshead .	362	21-	257	60		0·6	0·6	0·3
„ „ .	37-	225	26-	65		„	„	„

Dry Inches.

As it is a source of delay when gauging rapidly, to turn to the back of the rule for the purpose of casting out the ullages, especially when the casks are nearly full, as is usually the case on importation, it is as well to commit to memory the "dry inches," or depths of vacancy, which would require so many gallons to fill, or which would be the lowest point to cast out certain ullages clearly on the back of the rule. These dry inches run pretty much alike for the same descriptions of casks to the extent of 3, 4, or even 5 gallons, and the recollection of them serves to prevent the gauger from putting down what is called a "cut," or a dimension in which the lines of content and ullage on the back of the rule coincide exactly with each other, it being always desirable, in order to avoid dispute, that the ullage should show clearly one side or the other; if, therefore, the wet inches are so tight that a cut gauge would result, a tenth thrown off will make it cast clear, and is the more necessary, as, from the doubt that attends even the best gauging, more duty may be charged than fairly should, and the doubt is to be given, as a general rule, in favor of the merchant. This, however, applies more particularly to import gauging. In regauging, racking, &c., &c., the ullage is adjusted more closely to the content, according as the latter is rich or tight; and in gauging wines that have come from another Port of the United Kingdom, when 5 tenths of a gallon are counted as a gallon, in case of deficiency to that extent; also in gauging spirits, when the tenths are charged, and the ullages must be cast out separately.

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* These casks require, in addition to 3 tenths on the bung, one tenth on either the head or length, to make a clear gallon.

The following is a table of ullages for some of the varieties of casks, and the Gauger can easily construct others for himself experimentally, for any variety of cask he may be gauging:—

	1	2	3	4	5	Gallons.
	In.	In.	In.	In.	In.	
Port Pipes. . .	1·3	1·9	2·4	2·9	3·3	All these dimensions must be read as the *last* that will cast the number of gallons in the column under which they stand, clearly on the rule.
Sherry Butts . .	1·4	2·0	2·6	3·1	3·6	
Marsala . . .	1·3	2·0	2·5	3·0	3·5	
Port Sherry } Hogsds. Lisbon	1·6	2·5	3·3	2·8	4·3	
Ditto Qr. Casks .	2·0	3·0	3·8	4·6	5·6	

DISTILLATION,

AND ITS USE IN ASCERTAINING THE AMOUNT OF PROOF SPIRIT IN WINES.

Hitherto wines have been subjected to a uniform rate of duty per gallon (differing only in favor of Colonial produce); and a knowledge of their strengths has only been required when they have been suspected of exceeding the per centage of spirit allowed by law to wine; and beyond which they were liable to duty as mixed spirits, for the ascertaining of the strength of which the hydrometer is inapplicable. This limit, which was formerly 33 per cent., has of late years been advanced to 40 per cent., being at the least double the average natural strength of wines.

Notwithstanding this large margin, many wines, especially ports and sherries, and wines of a similar character from other countries, have exceeded the limit, and, being inadmissible for home consumption at the wine duty, and the rate as mixed spirits being virtually prohibitory, have been returned to the port of shipment, or left in bond until, by evaporation, the amount of spirit has been sufficiently reduced to remove the difficulty that barred their delivery in this country.

Seeing that the hydrometer does not serve our purpose in estimating the strengths of wines, in consequence of substances, other than alcohol and water, which are present and interfere with its action, we have to make use of other means, of which there are several. Of these, the most exact and advantageous is the process of Distillation, the use of which will be still more requisite under the differential duties of the new Tariff.

Before describing the actual mode employed for Revenue purposes, a few remarks will be advisable as to the principle of

Distillation, after which we shall better understand the practice.

Water, at the ordinary pressure of the air, and on the level of the sea, boils at 212° Fahr., at which temperature it rises as an invisible vapor, and would continue in this state were its temperature maintained unchanged. Passing into the colder air, however, it is manifested as a cloudy vapor, in which state it is commonly called steam, though it consists in reality of very minute globules of finely-divided water: steam properly so called being invisible, and having all the mechanical properties of air or gas. The visible state is caused by the partial condensation of steam into its original state of water; and a further degree of cold would cause the drops to unite in the liquid form.

On holding a cold plate against the spout of a kettle while the steam is issuing, the surface is first dulled as with a mist; gradually drops of water form; and these again unite and fall, unless the heat of the steam raise the temperature of the plate sufficiently high to evaporate the deposit, when no further condensation will take place. If by any means the coldness of the surface had been maintained, the deposit would have been continued, and in time a quantity of water would have accumulated. But this process would be both tedious and wasteful; a large portion of steam would escape uncondensed, and a mere fraction of the whole would be procured as water. What had been obtained, however, would be *distilled* water, and would have been freed in course of the process from any non-volatile impurities that may have been held in solution.

Instead of the mode just described, let the steam be prevented from escaping, and conveyed through a long tube immersed in cold water; (such tube may for convenience be bent spirally, when it is called a worm;) the whole of the steam will now be condensed, and we shall obtain all the water, purified, as the product of the operation.

Should the water contain in combination anything that will evaporate by heat, both will pass over together, unless the temperatures at which they arise in vapor differ, in which case we have a means of effecting a separation of greater or less completeness, subject to the control of other influences.

As our question lies entirely with the separation of alcohol from water, &c., we will confine ourselves to these.

Wines and spirits are all compounds of alcohol and water, the former having in addition mucilaginous and saccharine matters derived from the grape; the latter merely containing small quantities of essential oils and coloring matters generally inappreciable in Revenue practice.

Alcohol pure and entirely freed from water, or anhydrous, in which state it is procured by a careful process, is a highly inflammable, colorless liquid, having a specific gravity of ·792 at 60° Fahr.; it boils at 173°, and rises in vapor. When mixed with water, the compound boils at a temperature intermediate between 173° and 212°, which varies according to the proportion of each ingredient. As the alcohol is more readily volatilized, it rises first, but always in company with more or less water. Hence, by exposing the mixture to heat, and condensing the vapor, we can obtain a more concentrated spirit.

Repeated distillation, or better still, a process by which the effect of repeated distillation is produced in one operation, procures a high degree of strength, limited, however, by the extraordinary affinity which alcohol possesses for water, and which prevents our obtaining by this mode a higher degree of strength than a specific gravity of ·838 or ·840; beyond this, chemical means must be resorted to. The entire separation can only be effected by the aid of something having a stronger affinity for water than alcohol has; fresh burnt quick lime is ordinarily used for this purpose, as also many other substances with a like attraction for water. The description of the process, however, is unnecessary here.

In estimating the proportion of alcohol in wines, &c., by distillation, it is not requisite that it should be obtained pure, nor even in a highly rectified state; it will be sufficient for our purpose if we get the *whole* that is contained in the quantity experimented on, and free from every other admixture than pure water. The per centage of proof spirit can then be readily estimated by Sikes's Hydrometer.

It is important that the operation for Revenue purposes should be rapid, and still more important that it should be correct in its result; and these requisites are nicely combined in the mode now in use at the Custom House. A brief description of the apparatus with which it is effected will serve to explain its principles and practice.

A reference to the illustration at the end of this work, kindly lent by the manufacturers, Messrs. Jackson and Townson, of 89, Bishopsgate Street Within, London, will assist in comprehending the description.

The wine to be tested is measured in a vessel having a mark to indicate the proper quantity—3,000 grains. It is then placed in the still-flask, or retort to be distilled. This retort is a conical glass vessel, having a flat bottom, and a neck at the upper part, to which a brass cylindrical screw is cemented, for the pose of connecting it with the tube leading to the condenser. In instruments of more recent make, a new form of connection has been devised by the Principal Inspector of Gaugers in London, which, while it ensures a steam-tight joint, is more rapidly affixed than the other, and not liable to be disordered by the screw becoming loosened from the flask. The neck of the flask is made with a stout lip all round, and is held firmly to the tube (a Vulcanised India Rubber washer being placed between) by means of three brass hooks kept in place by a sliding ring, and adjusted by a screw, and which, on the ring being slipped up, release the neck from their grip, and allow its removal. The bottom of the flask is made exceedingly thin, to allow the rapid passage of the heat to the liquid within, and to render it less liable to crack from the changes of temperature to which it is subjected; while its breadth and flatness expose a greater surface of the liquid to the action of the flame than is the case in ordinary retorts.

The tube proceeding from the neck of the retort passes into a metal box called the condenser, which is fixed on a stand supporting the whole apparatus. On entering the condenser the tube is flattened to increase the surface exposed to the cold water, and is folded backwards and forwards in order to have as great a length as possible within. At the bottom of the opposite end of the condenser it emerges as a curved spout, from which the distilled liquid runs into the vessel placed to receive it.

The wine is heated by means of an ingenious application of gas, in which the advantages of a spirit lamp are combined with greater cheapness and convenience of use.

An argand burner, fixed on a stand, and supplied with gas by a flexible tube for the purpose of portability, has a brass cylinder placed round it in the manner in which the glass chimneys are usually attached. This cylinder is open at the bottom, but at the top is covered with a fine wire gauze. On turning on the gas it rises in the cylinder, mixing at the same time in explosive proportions with the atmospheric air which enters at the lower part.

This mixture, escaping with reduced velocity through the wire gauze, is ignited on the outside, forming a lambent, smokeless flame, producing intense heat. At the same time the flame is prevented passing to the gas in the cylinder below, by that peculiar property of wire gauze which hinders the transmission of flame; and which led to its application by Sir Humphrey Davy to the Miners' Safety Lamp.

By means of this flame the wine in the retort is rapidly evaporated, the steam entering the condenser, where, by the action of a constant stream of cold water passing through the box and abstracting the heat from the flat zigzag tube within, it is reduced to the liquid form, and runs rapidly from the spout, slackening a little towards the close of the operation, when, the bulk of the spirit having passed over, the water, which then forms the principal product, is evaporated and condensed with more difficulty in consequence of the higher temperature required to boil it, and the greater length of the tube it has to pass before complete condensation is secured.

The boiling is urged until the whole of the spirit has passed over, which in general with the quantity used for analysis, is about 8 to 9 minutes. The receiver now contains all the alcohol, together with some of the water of the wine; and is free from anything to interfere with the proper action of the hydrometer. It is then made up with distilled water to the exact bulk of the wine used in the experiment, (and to ensure perfect accuracy in this respect, the temperature of the distillate should be the same as that of the wine before distillation,) and placed in a tube large enough for the hydrometer to act in, when the temperature and indication are taken in the usual manner, as described under the head of Strengths of Spirits.

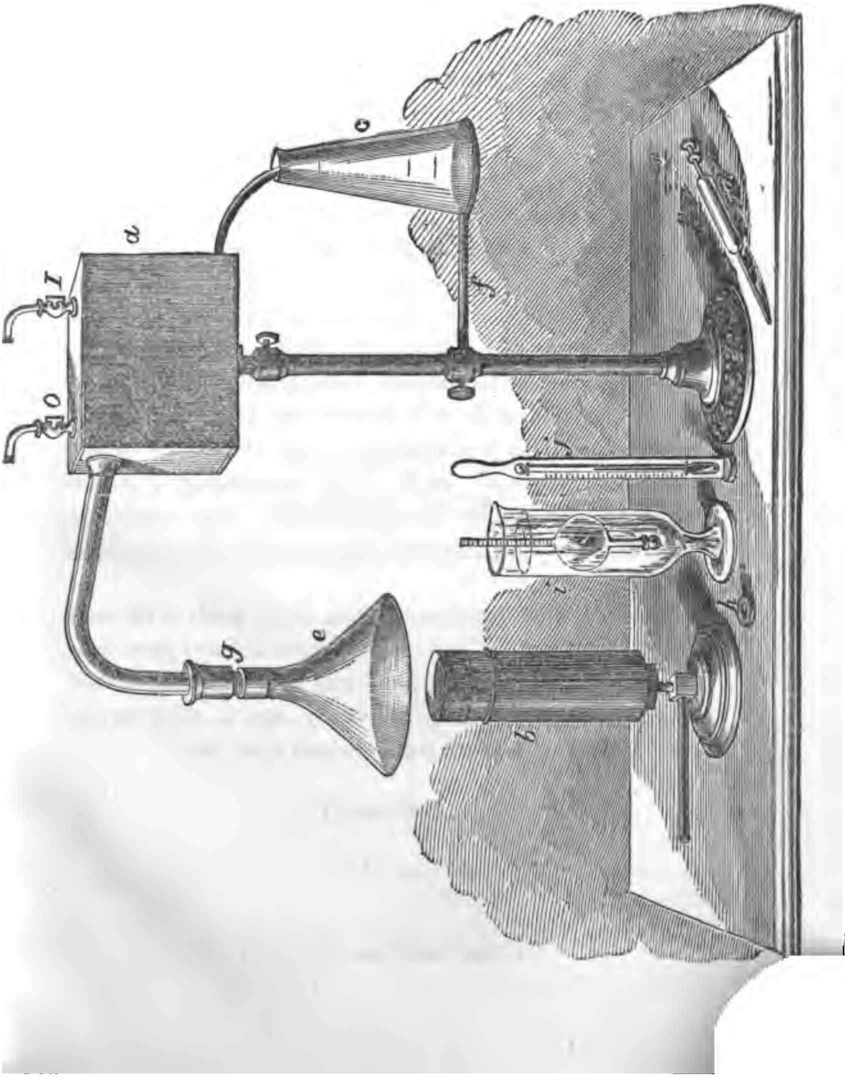
The strength per cent. found in the tables, and which is invariably under proof in the distillate, is then deducted from 100, and the remainder is the per centage of proof spirit in the wine under operation. Thus, let the per centage strength found be 64·2; then 100—64·2=35·8, the amount per cent. of proof spirit in the wine.

The working out of this analysis properly, simple as it really is, requires great care and delicacy in the manipulation, to ensure accuracy. The glass vessels in use must be handled tenderly and kept scrupulously clean; the stream of water through the condenser must be kept properly in action; the gas flame carefully controlled; and the quantity of wine for distillation, and the dilution of the product afterwards, must be measured with extreme exactitude, or the result cannot be depended on.

REFERENCES TO ILLUSTRATION OF THE WINE SPIRIT CONDENSING STILL.

a. Condenser.
b. Gas lamp, with metal chimney and wire gauze top.
c. Standard measure glass.
d. Pipette or dropping tube for ensuring accuracy in filling the measure glass to the required quantity.
e. Still flask.
f. Bracket to support the measure glass when in use as a receiver.

- *g*. Union for connecting still flask to condenser.
- *h*. Vulcanised India rubber washer, to make the joint steam-tight.
- *i*. Trial glass with Hydrometer.
- *j*. Thermometer.
- *I*. Tube for connecting the inflow pipe of water.
- *O*. Tube for outflow of do.



CONCLUDING REMARKS.

If the plan followed in this little treatise fulfil the aim of the author, the Pupil Gauger who has studied it fairly, will, it is hoped, have acquired an intelligent acquaintance with the general principles of his duty, and will need only time and practice to combine rapidity of operation with accuracy of result.

It will be well if, by observation and study, he mark out his own course of proceeding. Let him not take any of the foregoing rules for granted; especially let him not consider the general directions for the treatment of the casks of various countries as an unerring or unalterable guide for his practice. It is true that by acting on them he may, in a majority of cases, not go far wrong; but his errors, when they do occur, may happen at an awkward time, and lead to much difficulty of adjustment.

He must exercise the habit of thinking, and endeavour to be able to give a reason for what he does, and he will find the advantage not merely in gauging, but in all other things he may undertake. Above all, let him avoid encouraging a careless habit; and not consider the mere ability to pass rapidly with the rules over a large number of casks as any proof of excellence in his art.

In marking the dimensions in chalk on the heads of the casks and copying them into his book, let him make the figures bold, clear, and legible, as errors often arise from a difficulty in deciphering badly written ones; and, finally, bear in mind the proverb that "What is worth doing is worth doing well."

[THE END.]

John and James Keene, Printers, Bath.

Plate 1

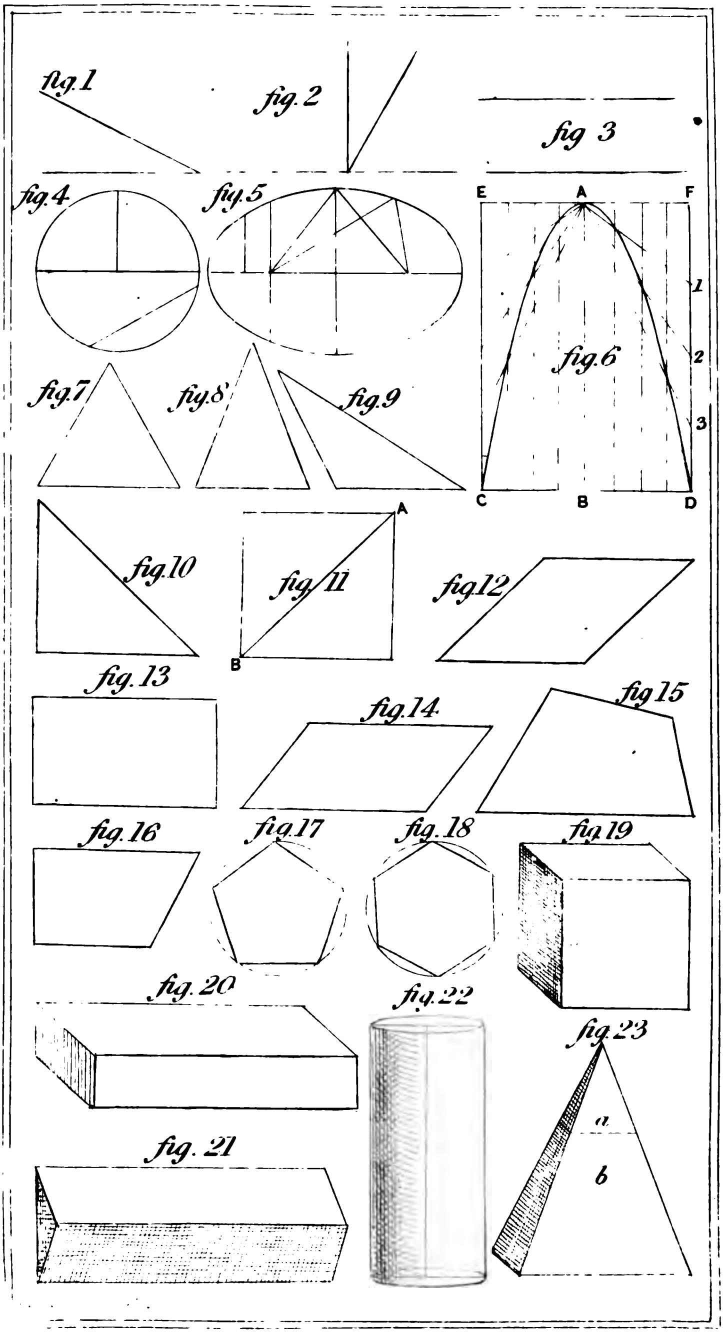


fig. 1
fig. 2
fig 3
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fig. 23
a
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fig. 21

Plate II

fig. 1

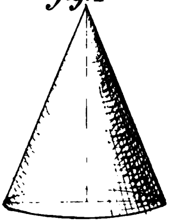


fig. 2

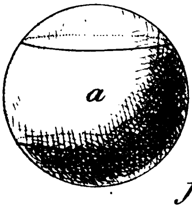


fig. 3

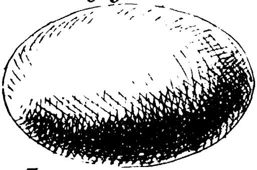


fig. 4

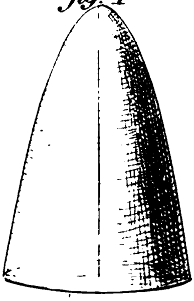
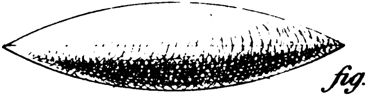


fig. 5.



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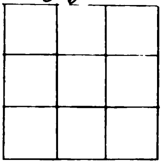

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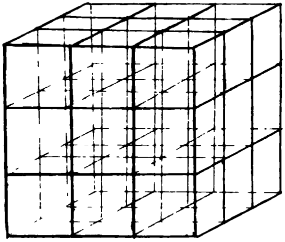

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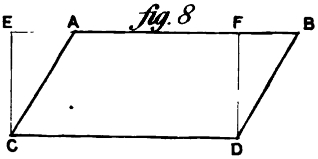

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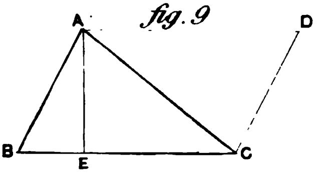

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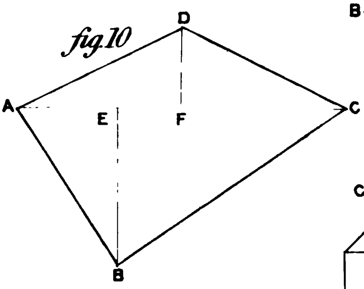

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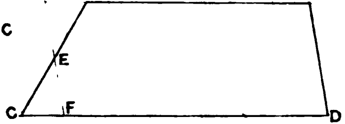

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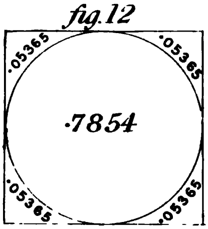

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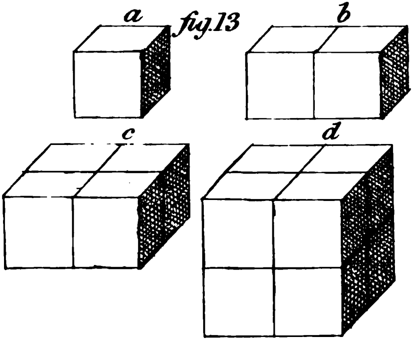

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Plate III.

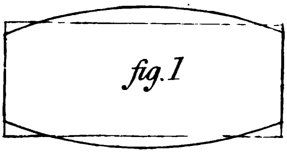


fig. 1

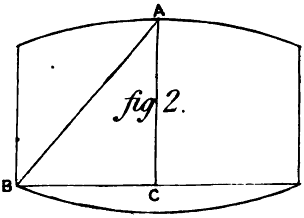


fig. 2.

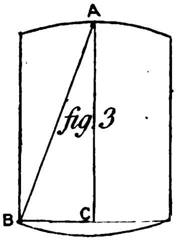


fig. 3

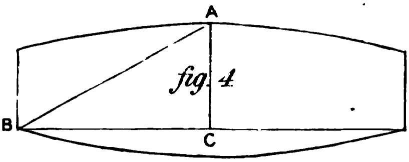


fig. 4

fig. 5

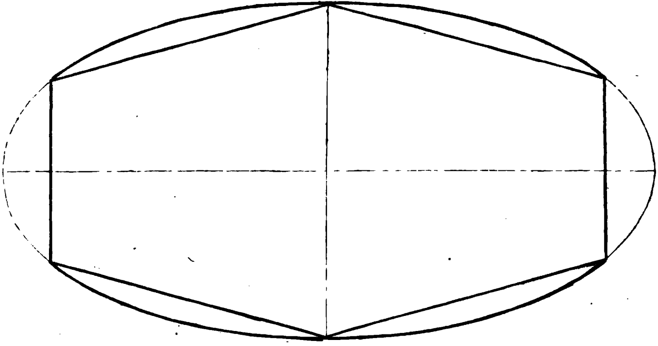
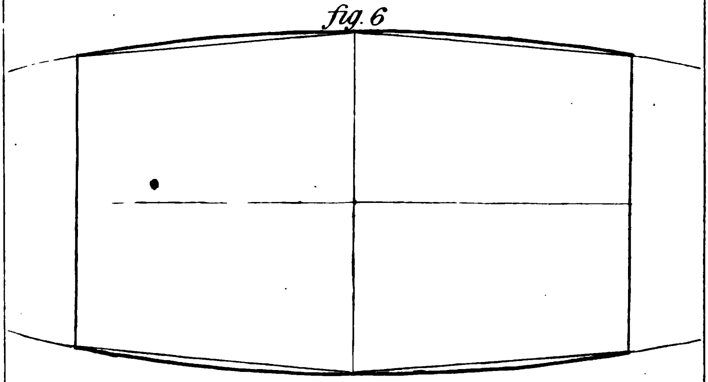


fig. 6



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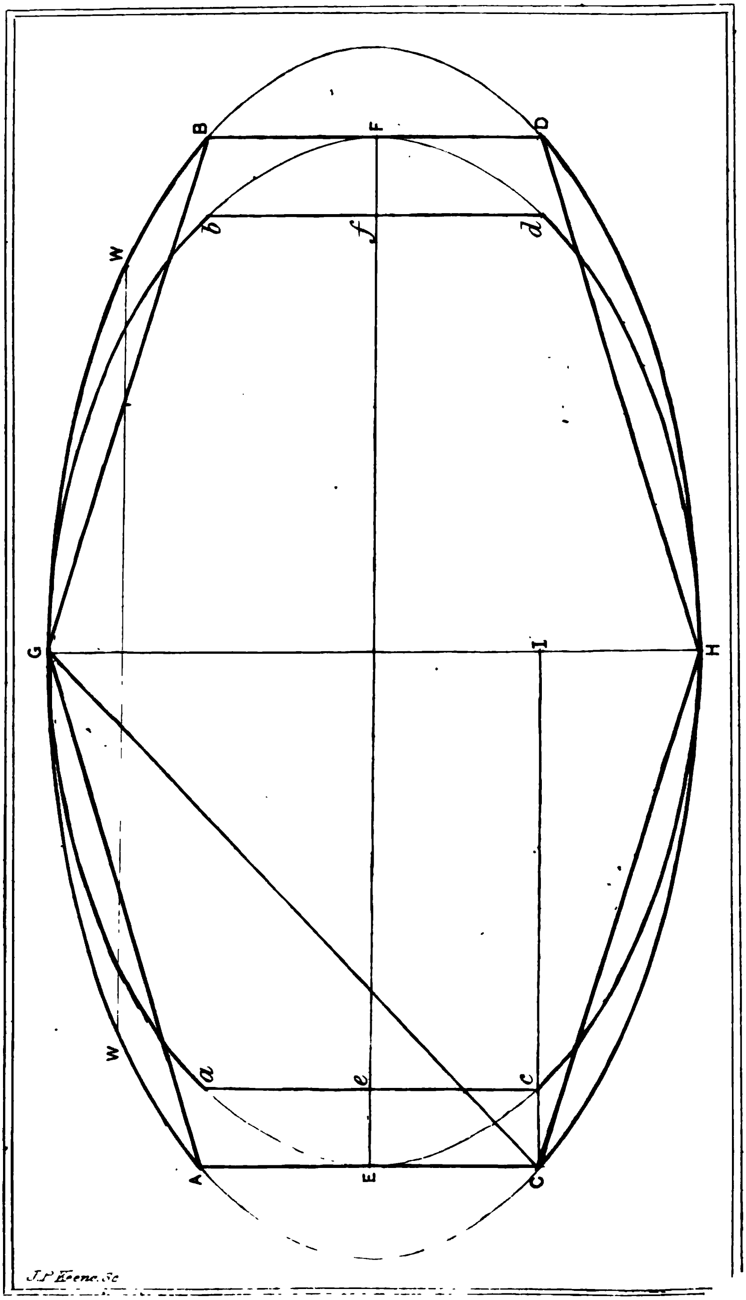

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Plate. V.

fig. 1

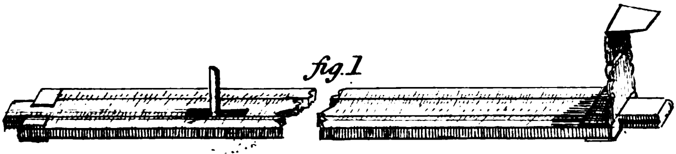


fig. 2

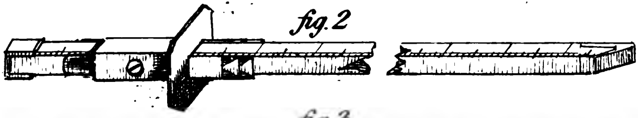


fig. 3

fig. 4

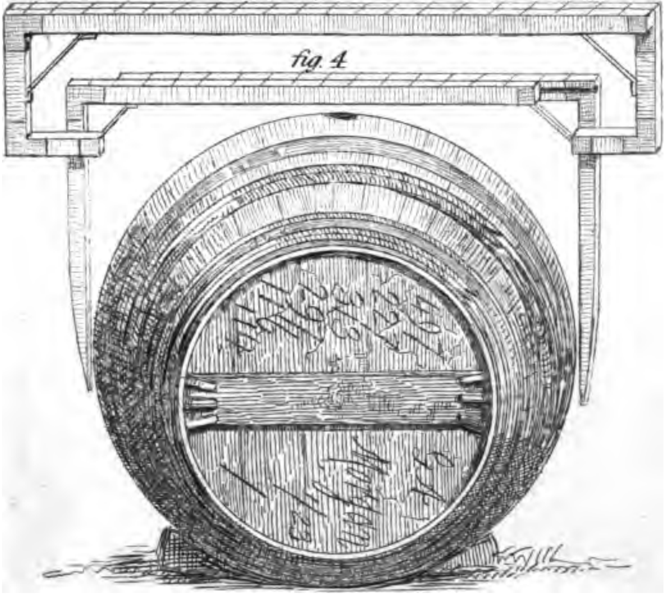
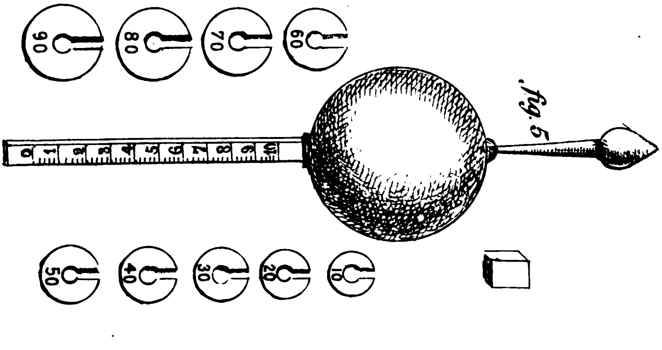


fig. 5



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